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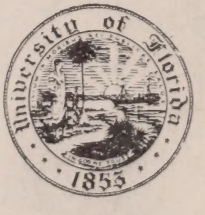

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

PREPARED UNDER THE DIRECTION OF
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United States Geological Survey

WASHINGTON
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ADVERTISEMENT.

The scientific publications of the United States National Museum consist of two series, the *Proceedings* and the *Bulletins*.

The *Proceedings*, the first volume of which was issued in 1878, are intended primarily as a medium for the publication of original, and usually brief, papers based on the collections of the National Museum, presenting newly acquired facts in zoology, geology, and anthropology, including descriptions of new forms of animals and revisions of limited groups. One or two volumes are issued annually and distributed to libraries and scientific organizations. A limited number of copies of each paper, in pamphlet form, is distributed to specialists and others interested in the different subjects as soon as printed. The dates of publication are recorded in the table of contents of the volume.

The *Bulletins*, the first of which was issued in 1875, consist of a series of separate publications comprising chiefly monographs of large zoological groups and other general systematic treatises (occasionally in several volumes), faunal works, reports of expeditions, and catalogues of type-specimens, special collections, etc. The majority of the volumes are octavos, but a quarto size has been adopted in a few instances in which large plates were regarded as indispensable.

Since 1902 a series of octavo volumes containing papers relating to the botanical collections of the Museum, and known as the *Contributions from the National Herbarium*, has been published as bulletins.

The present work forms No. 103 of the *Bulletin series*.

WILLIAM DEC. RAVENEL,
Administrative Assistant to the Secretary,
In charge of the United States National Museum.

WASHINGTON, D. C., September 15, 1919.

PREFACE.

Geologists generally recognize that knowledge of the geology of Central America is essential to solving the problems of the geologic history of the Americas, and many of them have devoted as much thought and study to the region as their rather occasional opportunities for investigation permitted. Among the previous investigators T. A. Conrad, W. M. Gabb, J. W. Gregory, W. H. Dall, H. Douvillé, P. Lemoine and R. Douvillé, M. Bertrand and Ph. Zürcher, R. T. Hill, and Ernest Howe should be mentioned. Since work on the Panama Canal was initiated by the United States Government, excluding the investigations associated with official duties, contributions have been made by Franz Toula, A. P. Brown and H. A. Pilsbry, and W. B. Scott.

In 1911 the Isthmian Canal Commission attached to its staff Dr. Donald F. MacDonald as commission geologist. In October and November, in 1911, I had the privilege of spending a full month in field work along the canal, largely as a guest of the Canal Commission, and I here wish to express to Maj. Gen. Goethals, then Col. Goethals, my very hearty thanks for the facilities afforded me. Doctor MacDonald and I, of course, worked together, and he left nothing undone in making our efforts successful.

Doctor MacDonald and I both recognized the extraordinary opportunity for making a highly valuable contribution, not only to the geology of Central America, but also to the geologic history of the continents to the north and south. As a result of our conferences, I suggested to the Director of the United States Geological Survey a plan for cooperation between the United States Geological Survey, the Smithsonian Institution, and the Canal Commission. He approved the suggestion and submitted it to the Secretary of the Smithsonian Institution, who also gave his approval. As a result of these preliminaries the following letter was prepared and sent to the chairman of the Canal Commission:

FEBRUARY 26, 1912.

Col. GEORGE W. GOETHALS,
Chairman Isthmian Canal Commission,
Washington Office, Washington, D. C.

SIR: As a thorough knowledge of the geology of the Panamic Isthmian region is essential to a solution of fundamental problems of the geologic history of both North and South America and of the adjacent oceanic basins; as the excavations for the Panama Canal and along the line of the relocated Panama Railroad offer opportunities during the next few years never before realized and probably never again to be realized

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for a geologic study of this region; as there is a scientific need for the extension of the geologic investigations beyond the Canal Zone to adjacent areas, and as these extended investigations, although they may not always bear directly on the problems of building the canal, will, by furnishing a basis for a wider knowledge of the geology of the area than can be obtained on the Canal Zone, be helpful in deciphering the local stratigraphy and structure of the rock formations cut by the canal, and will afford information on whether there are fuels, notably fuel oil, or other geologic products of economic value within reach of the canal:

The Smithsonian Institution and the United States Geological Survey desire to enter into cooperation with the Isthmian Canal Commission in making a study of the geology of the Canal Zone and extending the studies to adjacent regions so far as is feasible.

The following is submitted to the Isthmian Canal Commission for its consideration:

It is hoped and urged that the Canal Commission will continue in its service a commission geologist, and will provide facilities for his field work within the Canal Zone until the excavations for the canal for the Panama Railroad, and for any other projects that may require excavations have been completed and carefully studied. The Canal Commission is especially requested to permit the commission geologist to extend his examinations of the geologic formations and mineral resources beyond the Canal Zone, the salary of the geologist to be paid by the Canal Commission, and funds for his field expenses to be provided by the Smithsonian Institution. The commission geologist will, of course, submit to the Canal Commission a report of such nature and scope as the commission may direct.

The United States Geological Survey will, without charge, cut rock sections for microscopic study, make chemical analyses, and furnish special reports on fossils and other collections made and submitted by the commission. The advice of the different specialists on the survey will be at the service of the commission whenever their advice may be desired.

After the completion of the field work and after the commission geologist has submitted his report to the Canal Commission, the Smithsonian Institution desires to publish comprehensive and detailed monographic accounts of the physiography, stratigraphic and structural geology, geologic history, geologic correlation, mineral resources (including coal, oil, and other fuels), petrography, and paleontology of the Canal Zone and of as much of the adjacent areas in the isthmian region as is feasible. The services of the most eminent authorities will be enlisted in the preparation of special memoirs on the various collections made and submitted. The endeavor will be, by full presentation of all obtainable information, to make the Canal Zone the geologic standard of comparison for Central America as well as for portions of North and South America. In these reports due credit will be given to the Isthmian Canal Commission for its participation in the investigations.

We hope that this plan will meet with your approval and support.

Very respectfully,

(Signed) CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.
(Signed) GEO. OTIS SMITH,
Director, U. S. Geological Survey.

The proposed cooperation was approved by the chairman of the Canal Commission. Doctor MacDonald remained with the commission until the excavations in connection with the canal were completed and he made explorations outside the Canal Zone, especially along Banana River in Costa Rica, and in the Province of Los Santos (Azuero Peninsula) and from David northward to the volcano of Chiriqui, in Panama. He was also geologist for the Costa Rica-Panama Boundary Commission.

Doctor MacDonald's reports to the Canal Commission have been published in the annual reports of the chairman of the Canal Commission; and he is the author of a more lengthy paper entitled "Some engineering problems of the Canal Zone in their relation to geology and topography," published as Bulletin 86 of the United States Bureau of Mines.[1] Since the termination of his services for the Canal Commission he has completed a large report on the physiography, stratigraphic and structural geology, petrography, and economic geology of the Canal Zone. The transmission of this memoir for publication has been delayed because some of the paleontologic determinations were needed for interpreting the geologic history.

After the agreement to the proposed plan of cooperation, I took charge for the United States Geological Survey of the preparation of the special paleontologic reports, of the problems of geologic correlation, and of the coordination of the investigations with other work on the physiography, stratigraphy, paleontology, and geologic history in the southeastern United States and the West Indies. The paleontologic material was sorted according to groups, and the following specialists undertook monographic reports:

Dr. Marshall A. Howe, calcareous algae.
Prof. Edward W. Berry, higher plants.
Dr. Joseph A. Cushman, foraminifera.
Dr. T. Wayland Vaughan, madreporarian corals.
Dr. Robert T. Jackson, echinoids.
Dr. C. Wythe Cooke, mollusca.
Mr. F. Canu and Dr. R. S. Bassler, bryozoa.
Dr. Mary J. Rathbun, decapod crustacea.
Prof. H. A. Pilsbry, cirrepedia.

The few vertebrates obtained were identified by Mr. J. W. Gidley. All of the paleontologic reports are now complete except that on the mollusks. It was at first hoped that Dr. W. H. Dall would prepare the one on this group, but pressure of other work prevented him. Later Dr. C. Wythe Cooke, paleontologist of the United States Geological Survey, began a study of the collection of mollusks, but other duties have interfered with his prosecution of it. The recent papers by Toula[2] and by Brown and Pilsbry[3] have been used, and they are valuable, but they do not meet the needs of the present investigation, for the material described in them mostly represents one geologic formation, the Gatun formation, and the stratigraphic

[1] U. S. Bureau Mines Bull. 86, pp. 88, 29 pls., 9 text figs., 1915.

[2] Toula, Franz, Eine jungtertiäre Fauna von Gatun am Panama-Kanal, Geolog. Reichsanstalt Wien Jahrb., vol. 58, pp. 673–760, pls. 25–28, 15 text figs., 1909; Die jungtertiäre Fauna von Gatun am Panama-Kanal, Ibid., vol. 61, pp. 487–530, pls. 30, 31, 1911.

[3] Brown, Amos P., and Pilsbry, Henry A., Fauna of the Gatun formation, Isthmus of Panama, Acad. Nat. Sci. Phila. Proc. for 1911, pp. 336–373, pls. 22–29, 3 text figs., 1911; Fauna of the Gatun formation, Isthmus of Panama, II, Acad. Nat. Sci. Phila. Proc. for 1912, pp. 500–519, pls. 22–26, 5 texts figs., 1913.

data are not sufficient. It is probable that three and perhaps four horizons will be discriminated within the Gatun formation. Other groups of organisms are adequate for correlation purposes in most or all of the other geologic formations, but for the Gatun formation the principal reliance must be placed on the mollusks. The collections of mollusks made by Doctor MacDonald and myself is very extensive, and the greatest possible care was taken in obtaining full information on the stratigraphic relations of the material. It is hoped that a report commensurate with the size and importance of the collection may not be much longer delayed.

The series of papers here presented comprises all of the paleontologic memoirs that have been completed. These are immediately followed by descriptions of the geologic exposures where collections of fossils were made, with summaries of the fossils according to their stratigraphic occurrence, and a chapter on the geologic correlation of the fossiliferous formations, both with other American and with European formations. It is intended that Doctor MacDonald's comprehensive general report will be published soon after this series of memoirs has been issued.

The names of the geologic formations used in the paleontologic reports are the same as those employed by Doctor MacDonald in Bulletin 86 of the United States Bureau of Mines, to which reference is made on page v of this preface.

I wish to thank the officials of the Canal Commission, particularly Maj. Gen. Goethals, Director George Otis Smith, and Chief Geologist David White of the United States Geological Survey, and Dr. Charles D. Walcott, Secretary of the Smithsonian Institution, for the support they have given these investigations. To my colleagues outside the Geological Survey and United States National Museum, Dr. Marshall A. Howe, Prof. E. W. Berry, Dr. Robert T. Jackson, Mr. F. Canu, and Prof. H. A. Pilsbry, who has collaborated in this work, I am under deep obligations; and it is a pleasure to record my appreciation of the efforts of my official colleagues, Dr. D. F. MacDonald, Dr. Joseph A. Cushman, Dr. C. Wythe Cooke, Dr. R. S. Bassler, Dr. Mary J. Rathbun, and Mr. J. W. Gidley, all of whom have labored harmoniously to bring a large undertaking to a successful conclusion.

THOMAS WAYLAND VAUGHAN.

SEPTEMBER 15, 1919.

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CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

ON SOME FOSSIL AND RECENT LITHOTHAMNIEAE OF THE PANAMA CANAL ZONE

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ON SOME FOSSIL AND RECENT LITHOTHAMNIEAE OF THE PANAMA CANAL ZONE.

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Of The New York Botanical Garden.

INTRODUCTION.

The following report is based chiefly upon a number of specimens of fossil calcareous algae, of the group known to geologists as "Nullipores," from Oligocene and Pleistocene strata in the Panama Canal Zone, collected in 1911 by D. F. MacDonald and T. W. Vaughan, of the United States Geological Survey.

In this material the Pleistocene period is represented by a single collection (MacDonald, 6039), consisting of numerous excellent free specimens, "from flats near Mount Hope, five feet above tide level." These Pleistocene specimens appear to the writer to belong to a species found by him a year or two earlier to be living in the Colon region, only a few kilometers distant. This species, so far as the writer can determine, has been hitherto undescribed; in framing its diagnosis, as published below, the fossil as well as the recent material has been considered, but a recent specimen, being more complete and satisfactory for detailed study, has been named as the technical type of the species.

So far as the present writer has been able to discover, the fossil coralline algae of America, in their taxonomic aspects at least, offer a practically untouched field for research. It is, of course, possible that geological and paleontological papers in which calcareous algae have been described have escaped the attention of phycologists, but inquiry among American geologists and paleontologists and a search of accessible literature have thus far revealed to the writer but a single [1] hitherto described species of fossil Lithothamnieae from the Western Hemisphere, namely, *Lithothamnium curasavicum* K. Martin, from the Island of Curaçao, a species to which further allusion is made below in the discussion of *Archaeolithothamnium episporum*.

[1] *Stromatopora compacta* Billings (Palaeozoic Fossils, vol. 1, p. 55, 1862) from the Island of Montreal, etc., has sometimes been considered by geologists to be of corallinaceous affinities (the species has been referred to *Solenopora* by Nicholson and Etheridge, Geol. Mag., vol. 3, p. 529, 1885), but, if we may judge from published figures, the organism seems to the writer hardly a coralline alga, if indeed it is an alga at all.

The fossil Lithothamnieae of Europe have been described and figured in considerable number and with various degrees of care and detail. Most of these European descriptions and figures the writer has been able to see; some of them offer a reasonable basis for the future recognition of the forms concerned, without a reexamination of the original materials, but many of them do not. The present writer has had access to a good representation of the living Lithothamnieae of North America, the West Indies, Europe, and the East Indies, but so far as the fossil forms are concerned, he has had to depend upon descriptions and figures alone, which, as stated above, are often very unsatisfactory. In venturing to propose as new, two species of Lithothamnieae from Oligocene strata of the Panama Canal Zone, he doubtless risks the possibility that some future investigator, working with better materials or even with the same, may be able to convince himself or even to prove conclusively, that one or both of said species should be considered identical with species previously described from Europe. The diagnostic characters, the limits of variation, and the geographic range of even the living species are still very imperfectly understood. Some of the species are evidently widely distributed within certain temperature limits; others are at present known from single localities. So far as may be inferred from our present knowledge, very few, if any, of the forms of Lithothamnieae now living in tropical America occur also in European waters.

LIST OF SPECIES AND THEIR GEOLOGIC OCCURRENCE.

Archaeolithothamnium episporum, new species. Recent, Toro Point; and Pleistocene, Mount Hope; both in the Canal Zone.

Lithothamnium vaughanii, new species, Oligocene, Culebra formation at station 6026, about half way between Monte Lirio and Bohio Ridge.

Lithothamnium isthmi, new species, Oligocene, Emperador limestone at stations 6021, about 4 miles north of Gamboa Bridge, and 6024–*b*, Rio Agua Salud, Panama Railroad (relocated line).

Lithoporella melobesioides (Foslie) Foslie, Oligocene, Emperador limestone at station 6024–*c*, Rio Agua Salud, Panama Railroad (relocated line).

ARCHAEOLITHOTHAMNIUM[1] EPISPORUM, new species.

Plates 1 to 6.

Brownish red when living, the thallus forming at first widely expanded crusts 0.25–1.0 mm. thick, these in many cases repeatedly overgrown, the resulting crusts becoming 5 mm. or more thick, sometimes remaining nearly smooth or exhibiting the irregularities of the

[1] We follow Rothpletz's original spelling of the final syllable of this unfortunately long name, a spelling that, happily, agreer with Philippi's spelling of the final syllable of *Lithothamnium*.

substratum alone, but more often developing coarse, irregular rounded excrescences 5–12 mm. in diameter, or short rounded verrucae or nodules 2–5 mm. in diameter, the surface in sterile parts mostly smooth, indurated, and occasionally subnitent; hypothallia varying from weakly to strongly developed, 30–170 μ thick, their cells 17–28 μ by 8–11 μ; cells of the perithallium in distinct and regular layers except in oldest and youngest parts, the layers in more or less distinct zones, layers of short and of long cells occasionally alternating, cells mostly 8–15 μ by 5–8 μ, in decalcified condition submoniliate, sphaeroidal to ellipsoidal, 1–2½ times as high as broad, in calcified condition mostly subquadrate or oblong in vertical section: sporangia superficial, their apicula even with the surface, or slightly protruding, their cavities becoming only imperfectly and irregularly embedded, the sori slightly elevated, very irregular in outline, mostly 0.1–1.0 mm. broad, often widely confluent and anastomosing and becoming 5 mm. or more broad, the surface at length whitish and scarious, the ostioles mostly 16–22 μ in diameter, sporangia 65–96 μ high (including apiculum), 27–50 μ broad, 4-partite (occasionally 2-partite?), the spores irregularly paired or rarely subzonate.

Localities and geologic occurrence.—Covering dead corals, etc., and often forming concretionary pebbles with coral cores, from low-water mark to a depth of several meters, Point Toro, near Colon, Panama Canal Zone. Howe 6832 (type, in Herb. N. Y. Bot. Gard.), January 7, 1910; Colon, Howe 6840 (this covers continuously a mass of old coral 32 cm. long and 14 cm. in greatest width); also, as a Pleistocene fossil, "from flats near Mount Hope, five feet above tide level," D. F. MacDonald, station 6039,[1] 1911.

Paratypes.—Cat. No. 35298, U.S.N.M.

In outward form and in its habit of overgrowing old corals, *Archaeolithothamnium episporum* resembles *A. erythraeum* (Rothpletz) Foslie, f. *durum* (Heydrich) Foslie, from the Red Sea and the East Indies, especially as illustrated by Weber-van Bosse and Foslie (Corallinaceae of the *Siboga* Expedition, pl. 5). Of this species we have seen only one specimen (from near Makassar), communicated by Mme. Weber-van Bosse, but from this and from the descriptions and figures of *A. erythraeum* published by Foslie, Heydrich, and Lemoine, we infer that the Panamanian specimens represent a different species. Perhaps the most important distinctive character of *A. episporum* is to be found in its more superficial sporangia, as may be seen by comparing our photographs (pl. 2, fig. 1; pl. 3) with Heydrich's figure[2] of a vertical section through a sporangial sorus of his

[1] This is associated with minor amounts of other crustaceous corallines, including *Lithophyllum*, species, and *Goniolithon*, species.

[2] Ber. Deuts. Bot. Ges., vol. 15, p. 68, fig. 2. 1897.

Sporolithon ptychoides, which Foslie[1] and Lemoine[2] consider to be synonymous with *A. erythraeum*. The sori or the emptied sporangial cavities appear also to be much less regularly embedded or overgrown by new tissue than is the case in *A. erythraeum*, if one may judge from Rothpletz's original description,[3] Heydrich's figure 3,[4] Lemoine's figure 29,[2] and the descriptions given by the last-named writers; however, Foslie[5] remarks of *A. erythraeum* that "the sori are partly to be found overgrown in great numbers by new formed tissue, partly, however, they are not to be seen in section." In *A. episporum*, the sporangia themselves have never been seen except close to the surface; the emptied sporangial cavities do not show in a rough fracture or in an ordinary ground section, but irregular traces of them are often to be found in thin microtome sections of decalcified material. The sori of *A. episporum* are so superficial that their covering, after the discharge of the spores, appears to die and is flaked off together with more or less of the intersporangial parts, and the new tissue growing up from the base of the sorus shows only occasionally and imperfectly the outline of the former sporangial cavities.

Rothpletz's original description of his *Lithothamnium erythraeum* leaves one in some doubt as to whether he found the contents of the sporangium divided or undivided; he uses the term "Tetrasporen," but the measurements that he gives for these "Tetrasporen" are such as commonly belong to the whole sporangium in this group. In Heydrich's first description[6] of his *Sporolithon ptychoides*, the "Tetrasporangien" are said to be "meist ungetheilt, selten zweitheilig," but a little later[7] he figures four tetraspores in a sporangium, arranged in the "cruciate" manner. But this mode of division being at variance with the prevailing ideas as to the arrangement of the spores in the Corallinaceæ, Foslie,[8] a little later in writing a diagnosis of the genus *Archaeolithothamnium* inserted a question mark after "sporangia * * * unparted or cruciate?" and this sign of doubt as to the cruciate division has been repeated by later writers.[9] In *A. episporum* the mature sporangia are commonly and normally 4-parted in an irregularly "cruciate" fashion, but often the division axes of the two pairs of spores are at right angles to each other, so that only three spores are visible in a lateral view, and occasionally

[1] *Siboga* Exped. Monog., No. 61, p. 38. 1904.
[2] Ann. Inst. Océanog., vol. 2, pt. 2, p. 67. 1911.
[3] Rothpletz, A. Bot. Centralb., vol. 54, p. 5. 1893.
[4] Ber. Deuts. Bot. Ges., vol. 15, p. 68. 1897.
[5] *Siboga* Exped. Monog., No. 61, p. 41. 1904.
[6] Ber. Deuts. Bot. Ges., vol. 15, p. 69. 1897.
[7] Idem, pl. 18, fig. 3.
[8] Kgl. Norske Vidensk. Selsk. Skr. 1900, pt. 5, p. 8. 1900.
[9] De Toni, Syll. Alg., vol. 4, p. 1721, 1905; Svedelius, in Eng. & Prantl, Nat. Pflanzenfam., vol. 1, pt. 2; Nachtsäge, p. 267, 1911.

the second divisions seem to be omitted and the sporangium is apparently mature with only two spores. Very irregular types of division also occur, and rarely one finds an approach to the zonate[1] arrangement characteristic of most of the Corallinaceae.

The perithallic cells of *A. episporum* appear to be, in the decalcified state, more rounded and in more moniliform filaments than is the case in *A. erythraeum*, as may be seen by comparing our photomicrograph[2] with the photomicograph of a presumably decalcified section of *A. erythraeum*—published by Lemoine.[3] The distinct stratification of the perithallium of *A. episporum* is due, in part, to the alternation of layers of long and short cells, but we have never seen in the Panamanian species any such striking alternation of long and short cells as is shown in this photograph published by Mme. Lemoine and as is shown still more emphatically in Heydrich's figure 3[4] of a vertical section of his *Sporolithon ptychoides*.

From *Archaeolithothamnium dimotum* Foslie and Howe,[5] the only living species of this genus previously described from the West Indian region, *A. episporum* differs widely in its thicker crusts, in its more superficial sporangial sori, which are for the most part exfoliated after maturity of the sporangia and are only obscurely and imperfectly overgrown, in the usually larger, more rounded, and more moniliately arranged cells of the perithallium, the larger and rather less widely separated sporangial ostioles, etc.

Archaeolithothamnium curasavicum (K. Martin) Foslie,[6] a Cretaceous fossil from the island of Curaçao, is described and figured as showing distinctly rows of embedded sporangial cavities, such as would not be seen even in a thin decalcified section of *A. episporum*.

A Pleistocene fossil, collected by MacDonald at station 6039, from flats near Mount Hope, came from a few kilometers from the localities where we found the plant living, and we can entertain no serious doubt as to the specific identity of the recent and the fossil forms. The living and fossil are similar in external habit, as may be seen by comparing plates 1 and 4. They are similar also in their relations to old corals, and in structure (compare fig. 1, pl. 2, and fig. 4, pl. 5) they appear to exhibit only such differences as may be ascribed to individual variation or as may be expected in comparing the recent or living with the long dead. But little remains of the fossil speci-

[1] Zonately 4-parted sporangia have been described by Foslie for the Californian *Archaeolithothamnium zonatosporum* (Foslie, Algologiske Notiser. II. Kgl. Norske Vidensk. Selsk. Skr., 1906, pt. 2, p. 14), so that it would appear that this genus exhibits a wide variety in the matter of division of its sporangia.

[2] Plate 3, fig. 2.

[3] Ann. Inst. Océanog., vol. 2, pt. 2, pl. 1, fig. 1. 1911.

[4] Ber. Deuts. Bot. Ges., vol. 15. 1897.

[5] Bull. N. Y. Bot. Gard., vol. 4, p. 128, pl. 80, fig. 1; pt. 87, 1906.

[6] *Lithothamnium curasavicum* K. Martin, Bericht über eine Reise nach Niederländisch West-Indien und darauf gegründete Studien. II. Geologie, p. 26, pl. 2, figs. 22–25, 1888.

mens after decalcification, though the outlines of the cells may be recognized here and there. As microtome sections of the decalcified fossil material are out of the question, comparisons of structure of the recent and fossil must naturally be based upon calcareous ground sections. And in comparing the cell structure in sections of the recent decalcified specimens (pl. 3) with that shown in ground sections of the calcareous fossils, it is necessary, of course, to bear in mind that cells in calcareous ground sections of the Corallinaceae commonly appear much more rectangular than in decalcified sections of the same material.[1] In the sections of the fossil material thus far made there are no certainly recognizable traces of sporangial cavities, but this is true in almost an equal degree of calcareous ground sections of the recent specimens except as to the surface of the plant (fig. 1, pl. 2), where the sori are, in fact, so decidedly superficial or even exserted that they could, perhaps, hardly be expected to persist in the fossil state.

In the same locality with the type-specimens (Howe 6832) there occurs an outwardly somewhat similar plant (Howe 6837) that we at first suspected to be the antheridial form of *A. episporum*, but certain recognizable, though possibly unimportant, differences in the form, size, and zonation of the perithallic cells have restrained us from so considering it. The antheridial conceptacle (cavities) in this 6837 are 64–95 μ broad and 60–72 μ high; they become copiously embedded by the continued upward or outward growth of the thallus.

LITHOTHAMNIUM[2] VAUGHANII, new species.

Plate 7, figs. 1 and 2, and plate 8.

Thallus forming at first expanded crusts 1–2 mm. thick, these becoming overgrown, irregularly stratified, and 10 mm. or more thick, developing finally numerous, rather coarse, crowded anastomosing branches, and forming masses 2–4 cm. or more high; branches mostly 3–12 mm. in diameter, usually much flattened, occasionally subterete, often reduced to anastomosing ridges, or sometimes appearing as dome-shaped elevations 2 cm. or more broad; primary hypothallia somewhat reduced, their cells 14–33 μ by 8–14 μ, rather irregularly arranged (i. e., not distinctly "coaxial"), cells of medullary hypothallia mostly 15–30 μ by 5–13 μ, secondary hypothallia numerous and thin; branches showing in section numerous narrow irregularly flexuous, often subelliptic-lenticular or subcrescentic zones caused by

[1] For illustrations of these differences, see Lemoine, Ann. Inst. Océanog., vol. 2, pt. 2, p. 45, figs. 19–21, 1911.

[2] The writer believes, with Mme. Paul Lemoine, that the current rules of nomenclature require that Philippi's original spelling of this generic name should be respected, even though prevailing usage has modified the final syllable. Whether the rules of nomenclature justify the use of this generic name for any of the species now bearing it is a more complicated question.

the alternation of layers of short and long perithallic cells, or by the interpolation of reduced secondary hypothallia; the larger perithallic cells mostly 13–22 μ by 11–14 μ, usually higher than broad, the smaller subquadrate, about 8 μ square, or sometimes much compressed (7 μ high, 14 μ broad); conceptacles becoming embedded; tetrasporic conceptacles much flattened, oblong or elliptic-oblong in radio-vertical section, the cavity 500–740 μ in maximum width, 130–230 μ in height; roof of the tetrasporic conceptacle rather sharply defined, its cells in regular vertical rows of 1–4 cells, often elongate vertically, becoming sometimes 25–30 μ high.

Locality and geologic occurrence.—Oligocene, Culebra formation, "about half way between Monte Lirio and Bohio Ridge, on the relocated line of the Panama Railroad," collected by D. F. MacDonald and T. W. Vaughan, 1911 (station No. 6026).

Holotype and paratypes.—Cat. Nos. 35299, 35300, U.S.N.M.

The specimens obtained are more or less embedded in a hard rock matrix, so that our photograph (fig. 1, pl. 7) can give only an imperfect idea of the outward form of the plant. With a little mental clearing away of the matrix, it seems probable that in size and external appearance, the species may be compared with rather coarse eroded conditions of the living *Lithothamnium glaciale* Kjellman, but there is little similarity in structure; the perithallic cells of *L. vaughanii* average considerably larger than those of *L. glaciale* and they are arranged in more distinct layers; the embedded tetrasporic conceptacles of *L. vaughanii* are more flattened than those of *L. glaciale*, their cavities have about twice the maximum width of those of *L. glaciale* and the specialized character of the conceptacle roof is not noticeable in *L. glaciale*.

In external habit *Lithothamnium vaughanii* may perhaps be compared also with the living *Lithophyllum racemus* (Lamarck) Foslie forma *crassum* (Philippi) Foslie[1] of the Mediterranean and Adriatic seas, especially as shown in Hauck's figure 2[2] under the name *Lithothamnium crassum* Philippi, though the Panamanian fossil sometimes develops longer and perhaps more flattened branches than this form.

Of the living Lithothamnieae now known to the present writer as occurring in the West Indian region, *Lithothamnium vaughanii* per-

[1] Kgl. Norske Vidensk. Selsk. Skr., 1898, pt. 3, p. 9, 1898. Foslie's identification of *Lithothamnium crassum* Philippi as a form of *Lithophyllum racemus* (Lamarck) Foslie was accepted by Heydrich (Bot. Jahrb., vol. 28, p. 536, 1901), but Mme. Lemoine quotes *Lithothamnium crassum* Philippi as a synonym of *Lithothamnium calcareum* (Pallas) Areschoug. It is not, however, apparent that any of these writers examined authentic material of Philippi's *Lithothamnium crassum*, if such exists. It is of some interest, also, to note that less than six months before Heydrich accepted *Lithothamnium crassum* Philippi as a form of *Lithophyllum racemus* he named it as the type of a proposed new genus *Stichospora* (Ber. Deuts. Bot. Ges., vol. 18, p. 316, 1900).

[2] Hauck, F. Die Meeresalgen Deutschlands und Oesterreichs. In Rabenhorst, L., Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, vol. 2, pl. 1, 1885.

haps most resembles *Lithophyllum daedaleum* Foslie and Howe[1] as to general habit, but differs from it much in structure.

In the best section, No. 35299 U.S.N.M., the one from which the photographs (fig. 2, pl. 7 and pl. 8) were made, the coarse intersporangial sterile tissue of the tetrasporic conceptacles is scarcely shown, yet the roofs of the conceptacles show unmistakable canals and none of the conceptacles in section exhibits a single orifice, so that we consider ourselves justified in inferring that the specimen in question is tetrasporic and that it belongs in the genus *Lithothamnium* in the sense in which that name is currently applied to living plants. In a section from another specimen under the same collection number, traces of the sporangia and of the intersporangial sterile tissue are evident. It is to be observed also that the zonate arrangement of tissues, as observed in a section, is essentially of the character assumed by Mme. Lemoine[2] as being peculiar to the genus *Lithothamnium*. The rather distinctly specialized nature of the cells of the conceptacle roof is evidently a character of importance, in which respect it differs markedly from the plant we are describing as *Lithothamnium isthmi*, as also in the distinctly zonate structure of the thallus, the reduced hypothallium, the larger tetrasporic conceptacles, larger perithallic cells, etc.

Among the more fully described fossil Lithothamnieae, *L. vaughanii* may perhaps be compared with *Lithothamnium suganum* Rothpletz[3] from the Tertiary ("Scio-Schichten") of Val Sugana, near Borgo in the Austrian Tyrol, but the conceptacles of the Panamanian fossil are much larger (500–740 μ wide and 130–230 μ high vs. 250 μ wide and 100 μ high) and the perithallic cells appear to average considerably larger, being sometimes 13–22 μ high, while those of *L. suganum* are described as 9–12 μ long.

LITHOTHAMNIUM ISTHMI, new species.

Plate 7, fig. 3; plates 9, 10, and 11.

Thallus forming at first stratified crusts 3–12 mm. thick, but at length developing tortuous anastomosing branches and forming large rather solid, concrescent, fruticose masses; branches mostly 2–12 mm. in diameter, much flattened or subterete, often subconic-cylindric, flexed-digitiform, or molariform; hypothallia showing regular concentric layers of cells ("coaxial"); hypothallium of the crustaceous parts 160–480 μ thick, its cells 17–28 μ by 8–13 μ, transition to the

[1] Bull. N. Y. Bot. Gard., vol. 4, p. 133, pls. 83, 84, 93, 1906.

[2] Lemoine, Mme. Paul. Structure anatomique des Mélobesiées. Application à la classification. Ann. Inst. Océanog., vol. 2, pt. 2, pp. 27, 28, 1911.

[3] Zeits. Deuts. Geol. Ges., vol. 43, p. 319, pl. 17, fig. 4, 1891.

perithallium abrupt; medullary hypothallium of the branches mostly 0.6–2.0 mm. in diameter, often turning yellow and more or less disintegrated, its cells 17–44 μ by 8–13 μ, transition to the perithallium abrupt or gradual; cells of the perithallium in distinct layers, the layers in rather indistinct zones; perithallic cells of the crustaceous parts subquadrate, 8–11 μ in diameter, sometimes only 6 μ broad; perithallic cells of the branches usually a little higher than broad, 8–19 μ by 8–12 μ; conceptacles becoming embedded; tetrasporic conceptacles appearing much flattened in a vertical section, the cavity 240–550 μ in maximum width, 130–165 μ in height.

Localities and geologic occurrence.—In Emperador limestone of Oligocene age (and often constituting the dominant element in its composition) on relocated line of the Panama Railroad, opposite San Pablo, Panama Canal Zone ("first limestone outcrop just north of Caimito Station, about four miles north of Gamboa Bridge"), collected by D. F. MacDonald and T. W. Vaughan, 1911, Station No. 6021 (No. 35301, type); and "above foraminiferous marl at Agua Salud Bridge about ⅓ mile north of New Frijoles on relocated line, Panama Railroad," by the same collectors, Station No. 6024*b*.

Holotype and paratypes.—Cat. Nos. 35301 to 35303, U.S.N.M.

The material upon which the above description is based shows much variation in form and structure and it was our first impression that two or more species were represented in it. However, if this is true, the two or more species are so intergrown and entangled and are so similar in structure that it is difficult to determine where one begins and the other ends. As regards the vegetative structure, we believe that we have been able to trace the continuous organic connection of the two types shown in our photomicrographs (pl. 9 and fig. 2, pl. 11), yet it is notoriously easy in the case of overgrowing and overgrown fossil Lithothamnieae to mistake the close contact of independent plants for structural continuity.

In the tetrasporangial specimen (No. 35301—fig. 3, pl. 7 and pl. 9) that we have named as the type, the thallus presents itself in the form of irregularly superposed crusts, more or less overlaid by crusts showing a somewhat different structure and conceptacles of a different sort, these outer layers probably representing a crustaceous species of *Lithophyllum*. The hypothallium of this No. 35301 is suggestive of that figured by Foslie[1] for his living *Lithothamnium fragilissimum* from Borneo (which, however, has a much thinner thallus). It suggests also the hypothallium of *Lithothamnium lich-*

[1] Foslie, M. Lithothamnioneae, Melobesieae, Mastophoreae. In Weber-van Bosse, A., and Foslie, M. The Corallinaceae of the Siboga Expedition, *Siboga* Exped. Monog. No. 61, fig. 5, 1904.

enoides, as figured by Rosanoff[1] and by Lemoine,[2] but the crusts are evidently more massive than in that species.

Although the outward form of *Lithothamnium isthmi* is more or less obscured by being embedded in rock, it seems probable that in its typical condition (No. 35301) the external appearance of the plant may be compared with the recent plant from the Adriatic Sea figured by Hauck[3] as "*Lithophyllum decussatum* Solms," which Foslie[4] afterwards referred to his *Lithothamnium philippii*—a species that he maintained even after conceding[5] its specific identity with the earlier-published *Lithophyllum crispatum* Hauck. The typical form of Foslie's *Lithothamnium philippii* is said by him[6] "to have its hypothallium distinctly marked and vigorously developed, forming a coaxilate layer," but the "coaxial" character is essentially denied by Mme. Lemoine[7] to what she considers the same species under the name *Lithothamnium crispatum* Hauck. The perithallic cells of the crustaceous parts of *Lithothamnium isthmi* appear to average considerably smaller than those of *L. crispatum* (*L. philippii*) according to the measurements given by Lemoine and by Foslie. The tetrasporangial conceptacles of the *Lithophyllum decussatum* of Hauck (*Lithothamnium philippii* Foslie) are stated by Hauck to be "800μ bis 1 mm." in diameter, while in *Lithothamnium isthmi* they are only 240–550 μ in maximum width. Moreover, unless we are mistaken in connecting the fruticulose parts of the Panamanian fossil with the crusts, *Lithothamnium isthmi* develops numerous solid anastomosing branches, while in *L. crispatum* the short branchlike excrescences are mostly hollow, infundibuliform, or scyphiform. These fruticulose conditions, which comprise a large part of the material collected by MacDonald and Vaughan, suggest in external form certain states of the living West Indian *Lithophyllum daedaleum* Foslie and Howe, which also presents itself in both crustaceous and fruticulose conditions. Occasionally an unusually long subterete branch may resemble in form a frag-

[1] Mém. Soc. Imp. Sci. Nat. Cherbourg, vol. 12, pl. 6, fig. 14, 1866.

[2] Ann. Inst. Océanog., vol. 2, pt. 2, fig. 60, 1911. It is of interest to note that Mme. Lemoine, basing her system of classification primarily upon the vegetative structure of the thallus, leaves *Lithothamnium lichenoides* in the genus *Lithophyllum*, notwithstanding the fact that its tetrasporangia are borne as in the genus *Lithothamnium* of modern writers. In the same way she would doubtless place *Lithothamnium isthmi* in the genus *Lithophyllum*, even though this species (or its type at least) clearly has the tetrasporangial conceptacles of the conventional *Lithothamnium*.

[3] Hauck, F. Die Meeresalgen Deutschlands und Oesterreichs, pl. 1, fig. 7. See also pl. 1, fig. 1, of Foslie's Die Lithothamnien des Adriatischen Meeres und Marokkos (Wiss. Meeresuntersuch, Helgoland, vol. 7, pt. 1, 1904).

[4] Foslie, M. On some Lithothamnia. Kgl. Norske Vidensk. Selsk. Skr., 1897, pt. 1, p. 7, 1897.

[5] Wiss. Meeresuntersuch, Helgoland, vol. 7, pt. 1, pp. 13, 14, 1904.

[6] Kgl. Norske Vidensk. Selsk. Skr., 1900, pt. 1, p. 5, 1900.

[7] Ann. Inst. Océanog., vol. 2, pt. 2, p. 80, fig. 38, 1911.

ment of the living East Indian *Lithothamnium pulchrum* A. Weber and Foslie.[1]

Lithothamnium fosliei (Trabucco) De Toni (Syll. Alg., vol. 4, p. 1761, 1905), a Miocene fossil from Italy, is figured[2] as having a "coaxial" hypothallium, but from the illustrations given of the conceptacles, there is no sufficient ground for considering this plant to be a *Lithothamnium* rather than a *Lithophyllum*. In the original place of publication nothing but a figure (section) is given, from which, according to the scale of magnification given, it would appear that the conceptacles are only 140–160 μ by 80–90 μ and the perithallic cells about 16 μ high, making the cells rather larger and the conceptacles much smaller than in *L. isthmi*.

If we are correct in including with *Lithothamnium isthmi* the more ramified forms collected by MacDonald and Vaughan, the species, though commonly coarser, appears to be sometimes suggestive of plants figured as *Nullipora ramosissima* Reuss or *Lithothamnium ramosissimum* (Reuss) Schimper, from the Tertiary "*Leithakalk*" of the vicinity of Vienna, but Reuss's original figures and description[3] relate to external form only, and give no adequate basis for referring the plant to a modern genus. Unger[4] adds good figures of the vegetative structure, but shows no conceptacles. Rothpletz[5] describes the conceptacles of *L. ramosissimum* as 280 μ high, while the height of the conceptacles of *L. isthmi* is 130–165 μ and the width 240–550 μ. Rothpletz has no doubt that there are two species of Lithothamnieae in the "Leithakalk," which may have been confused.

LITHOPORELLA MELOBESOIDES (Foslie) Foslie.

Lithoporella melobesioides (Foslie) Foslie, Kgl. Norske Vidensk. Selsk., 1909, pt. 2, p. 50.

Mastophora melobesioides Foslie, Kgl. Norske Vidensk. Selsk. Aarsber., 1902, p. 24, 1903.

Locality and geologic occurrence.—This species occurs in small quantity with *Lithothamnium isthmi* in Emperador limestone of the Oligocene age, "above foraminiferous marl at Agua Salud Bridge about ⅓ mile north of New Frijoles on relocated line, Panama Railroad," D. F. MacDonald and T. W. Vaughan, 1911, Station No. 6024*b*.

EXPLANATION OF PLATES.

Plate 1.

Archaeolithothamnium episporum M. A. Howe.

Photograph, natural size, of the type-specimens, collected at Point Toro, near Colon, Panama Canal Zone, January 10, 1910 (Howe 6832). The technical

[1] Compare pl. 4, *Siboga* Exped. Monog. 61.

[2] *Eulithothamnium fosliei*, Trab. Boll. Soc. Geol. Ital., vol. 19, pl. 11, fig. 10, 1900.

[3] Haidinger, Naturw. Abh., vol. 2, pt. 1, p. 29, pl. 3, figs. 10, 11, 1848. Type from "Neudorfl," Hungary.

[4] Denkschr. k. Akad. Wiss. Wien, vol. 14, p. 23, pl. 5, figs. 18–22, 1858.

[5] Zeits. Deuts. Geol. Ges., vol. 43, p. 320, 1891.

type in a narrower sense is the specimen shown at the lower right-hand corner of the plate—the specimen from which figure 1 of plate 5 was obtained.

PLATE 2.

Archaeolithothamnium episporum M. A. Howe.

Photographs of radio-vertical ground (calciferous) sections of type material (Point Toro, Howe 6882).

FIG. 1. *Lithothamnium vaughanii* M. A. Howe. Photograph of the type-portion of a sporangial sorus, enlarged 42 diameters.

2. Section, enlarged 200 diameters.

PLATE 3.

Archaeolithothamnium episporum M. A. Howe.

Photographs of radio-vertical sections of decalcified material (Point Toro, Howe 6832), enlarged 200 diameters.

FIG. 1. Section showing sporangia and tetraspores.

2. Section showing emptied sporangia, form and arrangement of perithallic cells, a weakly developed hypothallium, etc.

PLATE 4.

Archaeolithothamnium episporum M. A. Howe.

A Pleistocene fossil, "from flats near Mount Hope, five feet above tide level," D. F. MacDonald 6039, 1911, natural size.

PLATE 5.

Archaeolithothamnium episporum M. A. Howe.

FIGS. 1 and 2. Photographs of the type material (Point Toro, Howe 6832).

FIG. 1. Portion of the surface, showing the more or less confluent sporangial sori, enlarged 4 diameters.

2. A smaller part of the same surface, showing the sporangial ostioles, etc., enlarged 25 diameters.

FIGS. 3 and 4. Photographs of Pleistocene specimen from Mount Hope (MacDonald, Cat. No. 35298, U.S.N.M.)

FIG. 3. Radiovertical section showing several superposed crusts and three well-developed hypothallia, enlarged 42 diameters.

4. A part of a cross section of one of the excrescences or branches, showing a single weakly developed hypothallium, enlarged 42 diameters. Compare structure of living specimen as shown in fig. 1, plate 2.

PLATE 6.

Archaeolithothamnium episporum M. A. Howe.

Photograph of section of the Pleistocene fossil from near Mount Hope (Cat. No. 35298, U.S.N.M.). A section magnified 73 diameters.

PLATE 7.

FIG. 1. *Lithothamnium vaughanii* M. A. Howe. Photograph of the type-specimens (between Monte Lirio and Bohio Ridge, MacDonald and Vaughan, Cat. No. 35299, U.S.N.M.), natural size.

2. *Lithothamnium vaughanii.* A section showing irregular zonation, tetrasporic conceptacles, etc., enlarged 42 diameters.

3. *Lithothamnium isthmi* M. A. Howe. A section, slightly enlarged (11/8 of the natural dimensions), showing the type-specimen embedded in the matrix (from about 4 miles north of Gamboa Bridge, MacDonald and Vaughan, station 6021). The type material (Cat. No. 35301, U.S.N.M.), from which the section shown in plate 9 was obtained, occupies the central portion of the light area and is overgrown by crusts of what appears to be a different plant, probably a species of *Lithophyllum*.

PLATE 8.

Lithothamnium vaughanii M. A. Howe.

An enlargement of a part of the section shown in figure 2, plate 7, illustrating form of perithallic cells, the reduced secondary hypothallia, the somewhat specialized roof of the tetrasporic conceptacles, etc. Magnification 100 diameters.

PLATE 9.

Lithothamnium isthmi M. A. Howe.

A section of the type material (MacDonald and Vaughan, station 6021, Cat. No. 35301, U.S.N.M.), enlarged 100 diameters. The section shows the well-developed "coaxial" hypothallium, the smaller-celled perithallium, and the conceptacles with the coarse intersporangial tissue characteristic of the genus *Lithothamnium*.

PLATE 10.

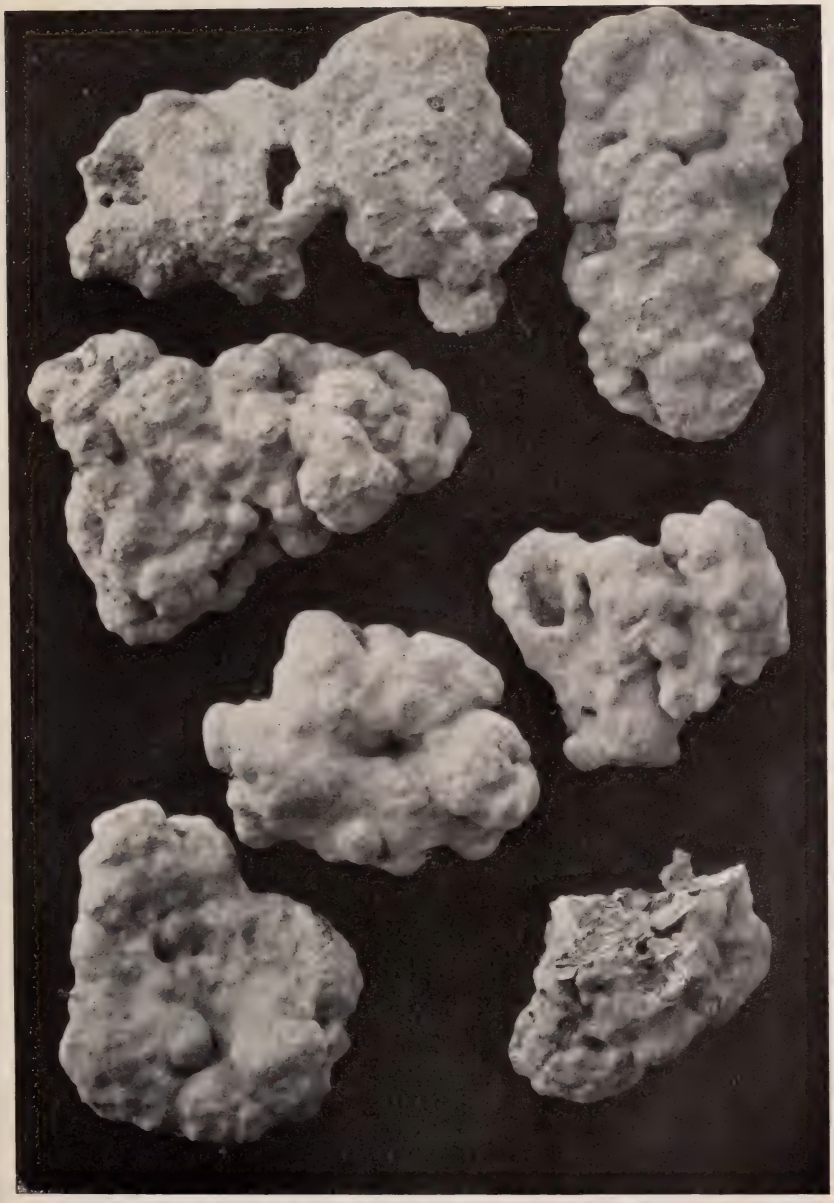
Lithothamnium isthmi M. A. Howe.

A specimen from about one-third mile north of New Frijoles (MacDonald and Vaughan, station 6024–*b*, Cat. No. 35305, U.S.N.M.), natural size, showing fossil embedded in matrix, in both weathered and freshly broken surfaces.

PLATE 11.

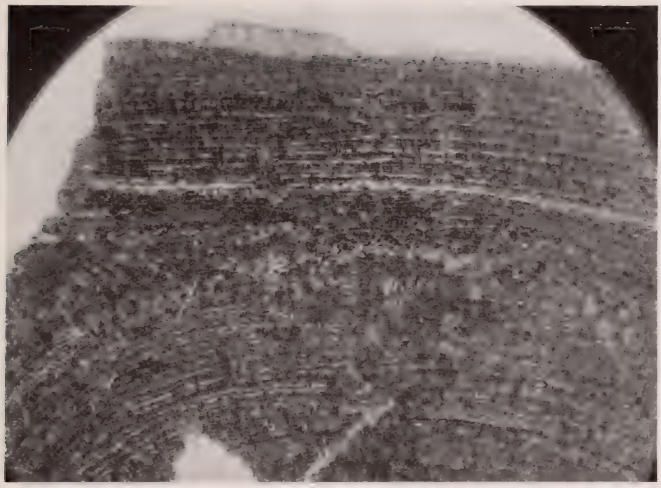
Lithothamnium isthmi M. A. Howe.

A somewhat obliquely transverse section of a branch (specimen from about 4 miles north of Gamboa Bridge, MacDonald and Vaughan, station 6021, Cat. No. 35302, U.S.N.M.), enlarged 106 diameters.



ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

FOR EXPLANATION OF PLATE SEE PAGES 11, 12.



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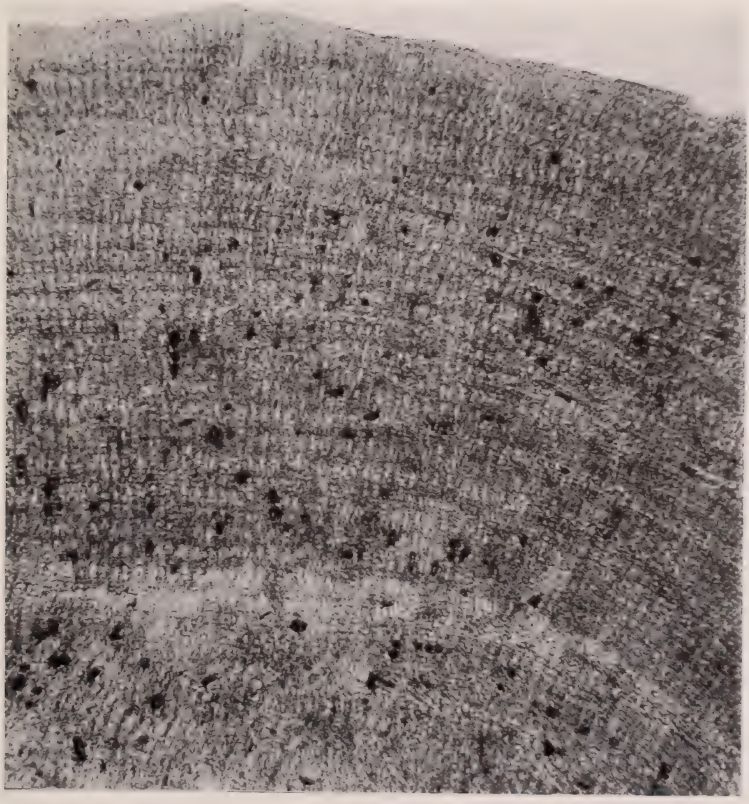

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ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

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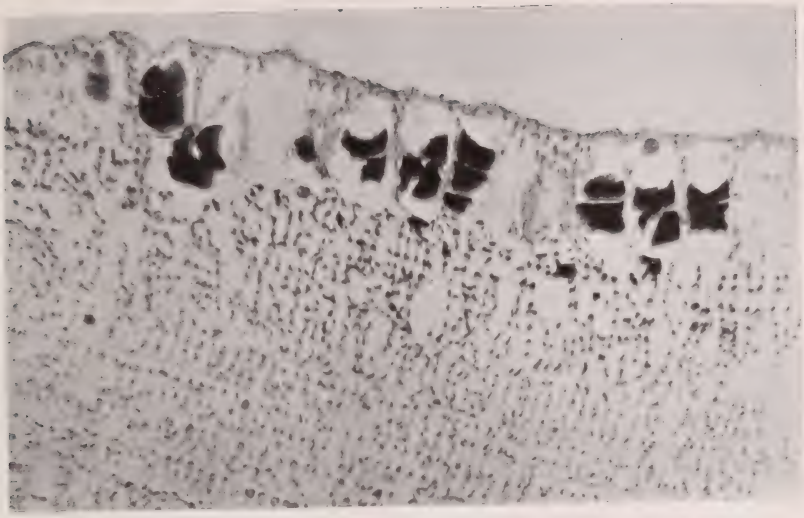

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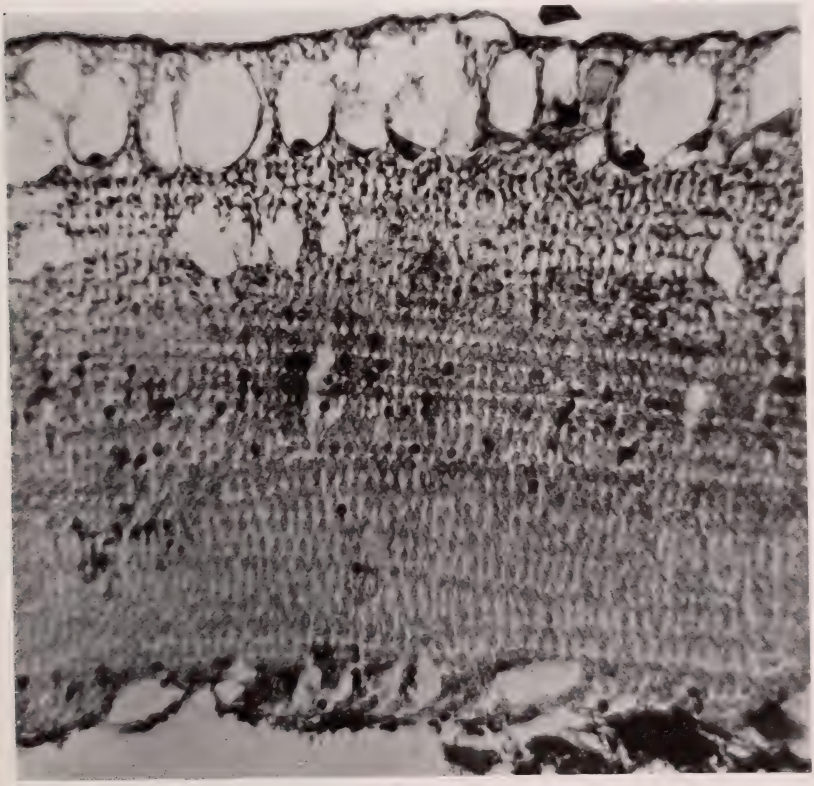

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ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

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ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

FOR EXPLANATION OF PLATE SEE PAGE 12.

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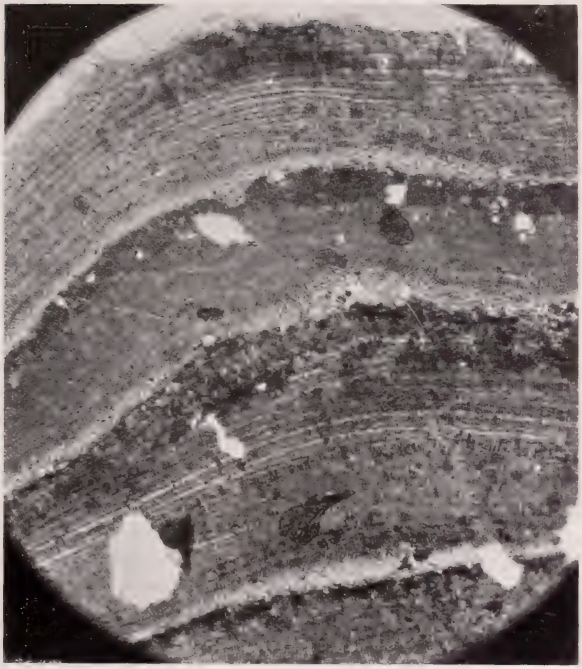

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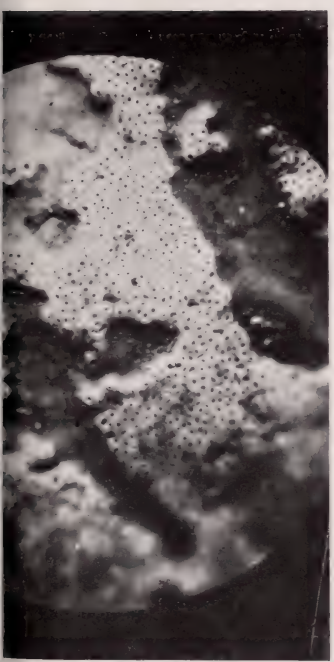

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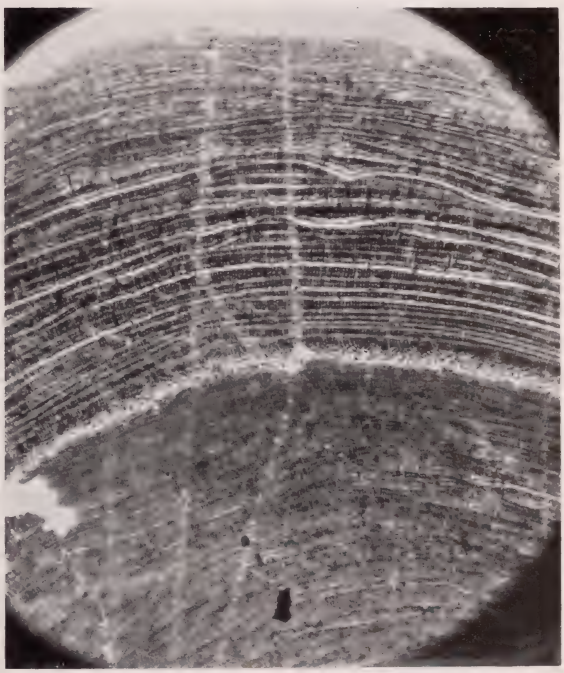

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ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

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ARCHAEOLITHOTHAMNIUM EPISPORUM M. A. HOWE.

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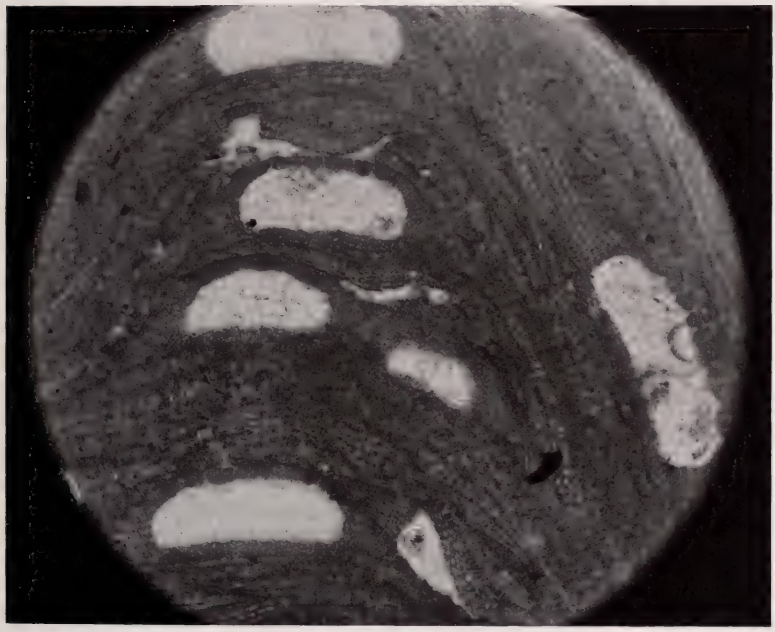

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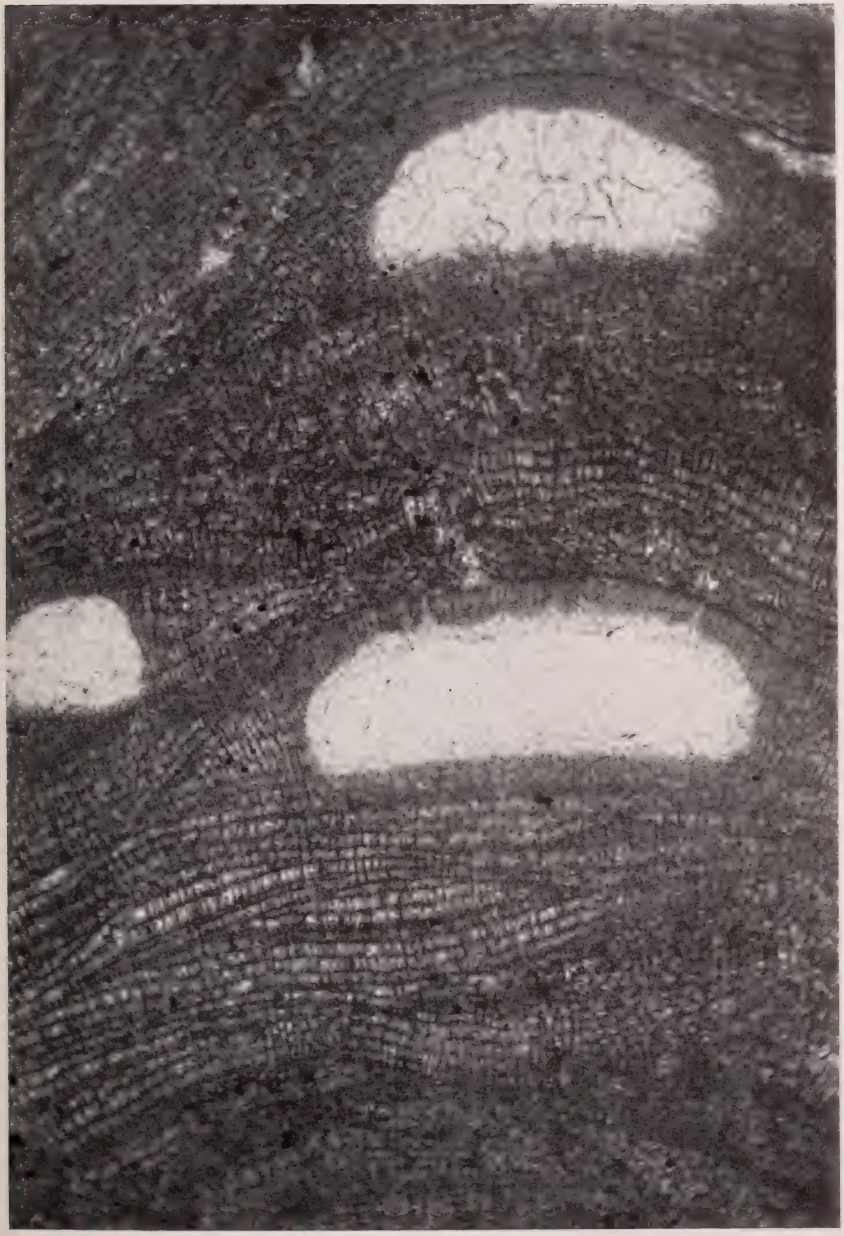
3

1, 2. LITHOTHAMNIUM VAUGHANII M. A. HOWE. 3. LITHOTHAMNIUM ISTHMI M. A. HOWE.

FOR EXPLANATION OF PLATE SEE PAGE 13.



LITHOTHAMNIUM VAUGHANII M. A. HOWE.

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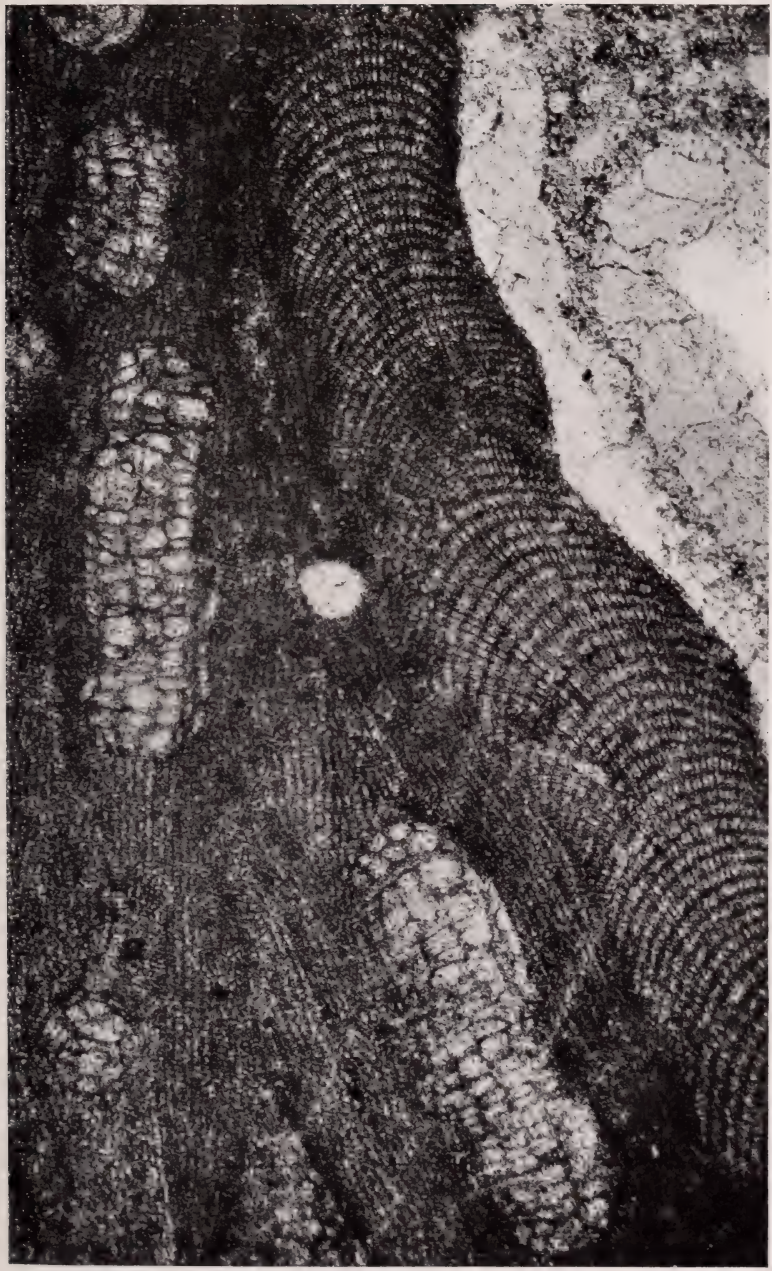

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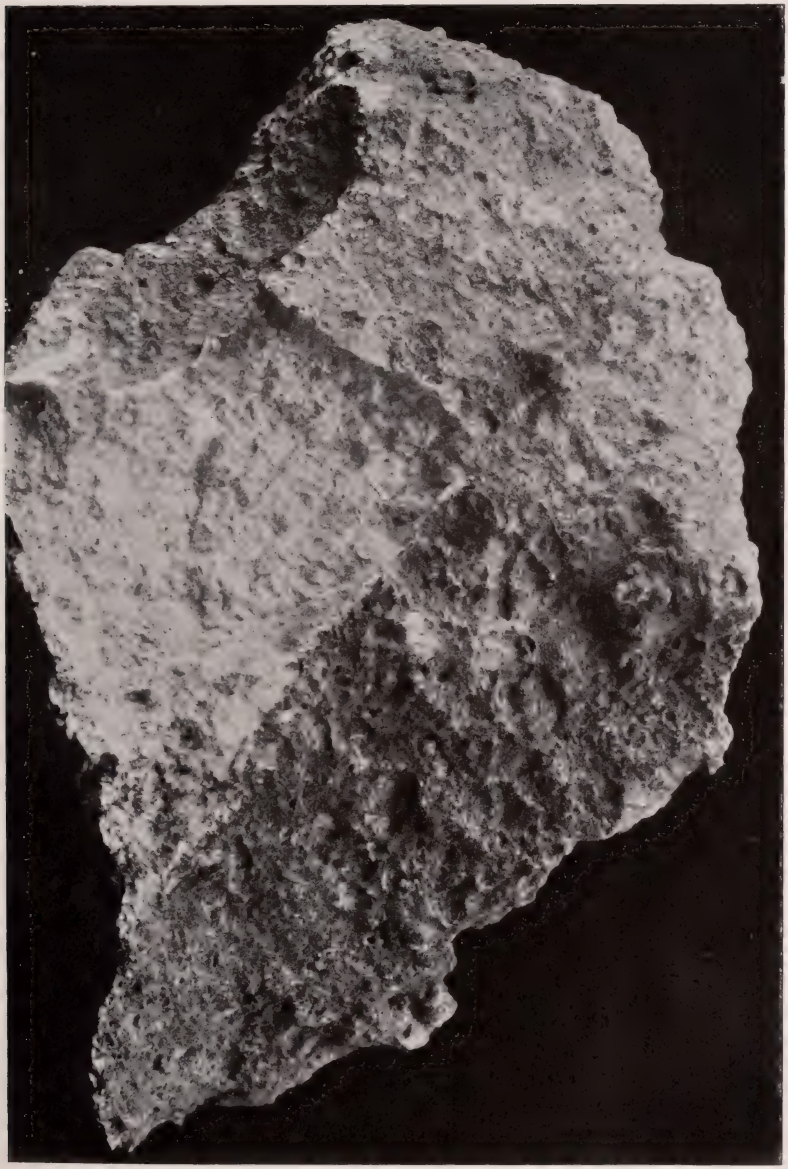

LITHOTHAMNIUM ISTHMI M. A. HOWE.

FOR EXPLANATION OF PLATE SEE PAGE 13.

LITHOTHAMNIUM ISTHMI M. A. HOWE.

FOR EXPLANATION OF PLATE SEE PAGE 13.

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

THE FOSSIL HIGHER PLANTS FROM THE CANAL ZONE

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Extract from Bulletin 103, pages 15–44, with Plates 12–18

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THE FOSSIL HIGHER PLANTS FROM THE CANAL ZONE.[1]

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INTRODUCTION.

It is a truism that the present floras and faunas of Central America are the result of a long series of antecedent geologic changes which might be amplified as geographic, climatic, and biologic. As the past can only be understood by means of our knowledge of the present, so, too, the present can only be understood by means of our knowledge of the past. Moreover, this can never be a local problem, and this is particularly true of the Isthmus of Panama marking as it does at times the highway of communication between the terrestrial life, both animal and plant, of North and South America; at other times marking one of the paths of communication between the marine life of the Atlantic and Pacific. Thus the history of the Central American region is of the utmost importance in any consideration of the extinct terrestrial faunas and floras of North America or the marine faunas that formerly flourished on the east and west coasts.

Our knowledge of the present flora of the isthmian region is based upon Seemann's flora[2] and Hemsley's flora of Central America, supplemented by the scattered papers by numerous authors on special topics relating to this flora. As the results of the recent Biological Survey of the Canal Zone become available, we will doubtless have a secure basis for comparisons with antecedant floras both in this region and the areas north and south of it.

The present distribution of plant associations is in its broader outlines governed almost entirely by the interrelations between

[1] R. T. Hill, who did some geological work on the Isthmus in 1895 for Alexander Agassiz, mentions lignite and fragments of fossil plants in the Culebra clays at the base of the canal cutting at Culebra station (Bull. Mus. Comp. Zool., vol. 28, No. 5, 1898), and the lignitic coal at Chiriqui Lagoon was studied by Dr. John Evans in 1857, who reported "that the fossil plants associated with the coal were endogenous and allied to or identical with those at present growing in the vicinity." (Repts. of Expl. & Surv. for the Location of Inter-oceanic ship canals, etc., by the U. S. Naval Exped., 1875, E. P. Lull, U. S. N., commanding, Washington, 1879.)

[2] Seemann, Flora Panamensis, Botany of the voyage of H. M. S. *Herald*, pp. 57–346, 852–1857.

topography and the prevailing winds and the resulting variations in rainfall.

The climate is now moist tropical, modified by the nearness of the two oceans, and there is therefore but slight diurnal or annual variations in temperature. So far as information is available regarding the conditions during the Tertiary, there is no evidence that can be deduced from the fossil flora or the geographical history of the region to indicate that the climate was very different from what it is now at any time during the Tertiary, unless we are prepared to assent to enormous changes in the altitude of the land, for which the data does not seem to be adequate.

The prevailing winds now come from the northeast, and as the divide is near the Pacific Coast the major part of the Isthmus north of this low divide has a heavy rainfall, as, for instance, 170 inches at Porto Bello and 129 at Colon, as compared with 90 inches at Culebra or 71 inches at Ancon. There are two seasons—a short relatively dry season extending from January to April and a long and relatively wet season the balance of the year with the maximum of precipitation from September to December. Before the clearing of the French Canal Company forests covered six-tenths of the Isthmus, the remainder being broken forests and savannas. Evergreen tropical rain-forests of mixed angiosperms covered the entire northern watershed and part of the Darien region on the south side. Some of the forests of the southern watershed are what are known as monsoon forests, with many deciduous species, and at high altitudes there may be more gregarious types of forest as, for example, the oak forests which are so striking a feature in the uplands of Central America as you proceed to the northwest.

The shores are skirted with dunes abounding in Leguminosae and Euphorbiaceae with Coco palms and Hippomane. Low shores and tidal inlets are covered with mangrove swamps with Rhizophora, Avicennia, Conocarpus, etc. Less saline coastal marshes are covered with Acrostichum, Crescentia, or Paritium thickets. The evergreen forest is composed chiefly of species of Sterculiaceae, Tiliaceae, and Mimosaceae, Euphorbiaceae, Anacardiaceae, Rubiaceae, Myrtaceae and Melastomataceae, with small palms like Chamaedorea, Trithrinax, and Bactris.

CORRELATION.

The fossil flora described in the present report is too limited for purposes of exact correlation, which may be expected to be settled by the marine faunas present at most horizons in the Isthmian region. Regarding the plants in the various formational units recognized in the Canal Zone by MacDonald a glance at the accompanying table of distribution will show that from the oldest (Bohio) to the young

est (Gatun) plant-bearing formations there is no observable difference in floral facies, and while the plants are entirely too few for positive conclusions, and while not much variation can be expected in fossil floras of the Tropics unless after the lapse of long intervals of time or the intervention of marked changes in physical conditions, I am disposed to think that this so-called Oligocene series of formations does not represent any great interval of time.

Nearly all of the fossil plants are new, the only outside occurrences being the *Hieronymia* which is common to the Tertiary of Ecuador and the *Palmoxylon* and *Taenioxylon* both of which occur in the Oligocene of the island of Antigua, and both have related types in the Oligocene (Catahoula and Vicksburg) of our Southern States In addition to the *Hieronymia* common to Ecuador there are several other elements in the Tertiary flora of the latter region that are similar to Panama forms, and it is not improbable that the coals of Loja in the Ecuadorian Andes are the same age as the so-called Oligocene series of Panama. Only one pre-Oligocene plant is recorded from Panama and the age (Eocene) rests on the stratigraphic observations of Doctor MacDonald and paleontologic determinations by C. W. Cooke. The form itself offers no intrinsic evidence of its age and might well be early Oligocene but for the fact that Doctor MacDonald collected the type stratigraphically below a bed containing a varietal form of the mollusk, *Venericardia planicosta*.

The chief question of interest in the correlation of these Panama beds is their equivalence in terms of the European section. The present flora offers no evidence on this point which must hence be determined by the accompanying marine faunas. However, in view of the traditional unscientific assumption that all of the fossiliferous beds of the Carribbean region are Oligocene in age, it is of interest to note that Douvillé[1] from a study of the foraminifera, pointed out as early as 1898, that a considerable part of the so-called Oligocene of the Isthmus was Aquitanian and Burdigalian in age; that is to say, lower Miocene according to the present conceptions of European geologists and palentologists.

In my preliminary announcement[2] of the discovery of fossil plants in the Canal Zone I stated that none of the plants recognized indicated Eocene and that they were all probably Oligocene in age. This statement was perhaps overemphasized in a desire to offset the extreme views of certain foreign paleontologists who have held that these faunas were young Miocene or even Pliocene.

The question of the exact time in the Tertiary at which connections between North and South America were replaced by marine conditions is of the utmost importance in all studies of distribution of both

[1] Douvillé, H. Bull. Soc. Géol. de France, ser. 3, vol. 26, pp. 587–600, 1898.
[2] Berry, E. W. Science, new ser., vol. 39, p. 357, 1914.

the marine faunas and the terrestrial faunas and floras. The floral evidence as previously stated is inconclusive. I should not, however, be inclined to consider any of the fossil plants, except one Eocene species, described in the present report as younger than Burdigalian nor older than Sannoisian (Lattorfian).

	Gatun formation.	Caimito formation.	Lower Oligocene Limestone.	Cucuracha formation.	Culebra formation.	Bohio formation.	Eocene.	Oligocene of Antigua.
Palmoxylon palmacites				6845 ×				×
Ficus culebrensis					6837 ×			
Guatteria culebrensis	×	6840 ×			×			
Myristocophyllum panamense					×			
Taenioxylon multiradiatum			6523 ×	6845 ×	×	×		×
Inga oligocaenica					6837 ×			
Cassia culebrensis		6840			6837 ×			
Hiraea oligocaenica		×						
Banisteria praenuntia					×			
Hieronymia lehmanni		×						
Schmidelia bejucensis		6840 ×			×			
Mespilodaphne culebrensis					×			
Calyptranthes gatunensis	×							
Melastomites miconioides					×			
Diospyros macdonaldi							6586b ×	
Rondeletia goldmani	×							
Rubiacites ixoreoides	×							
Palm rays					6839 × 6837	¼ mile S. of Empire Bridge.		
Fern fragments					6837 *cf.* Acrostichum.			

BOTANICAL CHARACTER.

The fossil flora at present known from the Canal Zone is extremely limited and entirely too small for either purposes of adequate correlation or for deductions concerning the true botanical facies or the environmental conditions. Seventeen species are determined and two or three additional forms are tentatively recognized. This paucity is especially to be regretted since it is improbable that under the existing climatic conditions as favorable opportunities for the discovery and collection of fossil plants will ever be presented as during the digging of the canal. While fossil plants were nowhere found to be abundant in the shales, nevertheless, it is very probable that an experienced collector by working over a large amount of

material could have gotten together a much more representative collection.

The plants collected include ill-defined fragments of one fern, two undertermined species of palm, represented by fragments of foliage, and a third represented by petrified stems, and 16 dicotyledons, of which two are represented by fruits and the balance by leaves.

Among the Dicotyledonae there are representatives of the orders *Urticales*, *Ranales*, *Rosales*, *Geraniales*, *Sapindales*, *Thymeleales*, *Myrtales*, *Ebenales*, and *Rubiales*. Orders conspicuous in the existing flora of the Isthmian region unrepresented among the fossils are the *Arales*, *Poales*, *Cyperales*, and *Orchidales* among the Monocotyledonae, and the *Campanulales* and *Personales* among the Dicotyledonae.

The following 14 families are represented by fossils in Panama: Moraceae, Anonaceae, Myristicaceae, Mimosaceae, Caesalpiniaceae, Papilionaceae, Malpighiaceae, Euphorbiaceae, Sapindaceae, Lauraceae, Myrtaceae, Melastomataceae, Ebenaceae, and Rubiaceae. Only the last, with two species, is represented by more than a single species. When so sparse and evenly distributed a representation of the families is present in a fossil flora, it is an indication that after allowing for some accidents of preservation, those families represented may be regarded as the most abundantly represented in the Tertiary flora of the region, and in this respect there is a very great similarity to the existing flora of the Isthmian region. The present forests of Panama are made up principally of species of Arecaceae, Moraceae, Mimosaceae, Papilionaceae, Sterculiaceae, Tiliaceae, Euphorbiaceae, Anacardiaceae, Myrtaceae, Melastomataceae, and Rubiaceae. The only ones of this list not found fossil are the Sterculiaceae, Tiliaceae, and Anacardiaceae, and as these three families are all abundant in the much more complete floras from the Tertiary of the southeastern United States, it is safe to assume that they were also present in the Tertiary flora of Panama. The mainly herbaceous families abundant in the Recent flora, which are hardly to be expected in the fossil flora, are the Poaceae, Cyperaceae, Orchidaceae, Araceae, and Compositae.

The bowers of wild figs of the existing flora are represented by a small-leafed species of *Ficus* from two localities in the Culebra formation. The family Anonaceae, which has numerous species of *Anona* and *Guatteria* in the Recent flora of Central America, is represented by a fine large species of the latter genus which is not uncommon in the Gatun, Caimito, and Culebra formations. *Guatteria* contains about 50 existing species of tropical shrubs and trees of varying habitats and exclusively American, and has not been previously recognized with certainty in fossil floras. *Anona* is abundant

in the Eocene and Oligocene of our Southern States, but *Guatteria* has not been recognized.

The Myristicaceae is represented by an infrequent species of *Myristicophyllum* in the Culebra formation, and in this connection it is of interest to note the presence of fruits and seeds of *Myristica* in the uppermost Eocene of Texas suggestive of the subgenera *Virola* and *Compsoneura*. both of which occur in the Recent flora of Central America. The Leguminosae have three fossil species. The Mimosaceae, which are very abundant in the existing forests of Panama, are represented by a fossil species of *Inga*, a large genus of tropical trees with upward of two-score species in Central America, nearly half of which are recorded from Panama. *Inga* is well represented in the abundant Eocene floras of our Southern States, and it is of interest to note the resemblance between the fossil species from Panama and a species described by Engelhardt from an unknown Tertiary horizon in Ecuador.

The Caesalpiniaceae is represented by a single species of *Cassia*, a large genus not only in the Recent equatorial floras but well represented in most fossil floras from the Upper Cretaceous to the present

The Papilionaceae, very abundant in the existing flora of Panama is supposed to be represented by the petrified wood of a large tree referred to the genus *Taenioxylon* and found in the Cucuracha Culebra, and Bohio formations.

The family of Malpighiaceae is represented by the genera *Hiraea* and *Banisteria*. The former has about 30 recent species, exclusively American, ranging from Mexico and the Antilles to tropical Brazil and Peru, and it is represented by a fossil species in the Eocene of the Mississippi embayment. *Banisteria* contains about 80 existing species, mostly climbing shrubs. It is at present confined to the American tropics, but appears to have been present in Europe as well as in the southern United States during the Tertiary.

The Euphorbiaceae, abundantly represented in the present forest of Panama, is represented in the Caimito formation by a species of *Hieronymia* apparently identical with one described by Engelhardt from the Tertiary of Ecuador. *Hieronymia*, not otherwise known in the fossil state, contains about a dozen existing species which are confined to tropical America, where they range from Mexico and the West Indies to Brazil.

The Sapindaceae, abundant in all fossil floras from the Upper Cretaceous onward, and exceedingly abundant in the Tertiary flora of the Mississippi embayment, is represented in the fossil flora of Panama by a species of *Schmidelia* found in the Caimito and Culebra formations. *Schmidelia* has a large number of existing species in the equatorial regions of both hemispheres and, except for petrified

material from the island of Antigua, it has not previously been recognized in the fossil state.

The family Lauraceae, so extensively represented in the Tertiary floras of the Mississippi embayment and in the Recent tropical flora of South America, is represented at Panama by a single fragmentary species which is referred to Mespilodaphne. The latter has numerous modern species in the tropics of America and Africa.

The Myrtaceae, one of the abundant families in the existing forests of tropical America, has a fossil species of *Calyptranthes* at Panama. This genus has about 70 exclusively American existing species ranging from Mexico and the West Indies to southern Brazil. Hemsley records 7 recent species from Central America, of which 2 are found on the Isthmus. It is also represented in the lower Eocene of the Mississippi embayment. The abundant, both Recent and fossil, representatives of the allied genera *Eugenia* and *Myrcia* have not been recognized in the fossil flora of the Isthmus.

The Melastomataceae, an immense tropical family in the existing flora and very abundant throughout Central America, has a single fossil species in the Culebra formation.

The family Ebenaceae, usually abundant in fossil floras from the Upper Cretaceous onward, and with a large number of species in tropical America, is represented on the Isthmus by the petrified fruits of a species of ebony (*Diospyros*) known to be from an older horizon (Eocene) than the balance of the known fossil flora.

The Rubiaceae, a prominent family in the existing flora of Central America, where according to Wallace (1911) it ranks fourth in size with 146 species, is represented by two fossil species, both found in the Gatun formation. These are referred to *Rondeletia* and *Rubiacites.*

The former has not heretofore been found fossil. It includes about 70 existing species of a variety of habitats, confined to the American tropics and chiefly massed in the Antilles and Central America. *Rubiacites* is represented by a fruit which is apparently referable to the tribe Ixoreae, now confined to the tropics of both hemispheres.

TERTIARY ECOLOGY.

The restricted variety and fragmentary condition of the fossil plants thus far collected inhibits a detailed discussion of the probable ecology of the Tertiary flora. In so far as climatic conditions are concerned the Tertiary plants indicate an abundant rainfall and relatively high equable temperatures such as prevail at the present time in the Hill country and Coastal Plain of the Isthmus. There is no indication of upland vegetation. None of the fossil plants indicate

mountains sufficiently high to harbor that mixture of temperate types such as is seen at the present time in the mountains of Central America, as, for example, above 6,000 feet in Costa Rica. There was plenty of opportunity for the introduction of such types had the climate been propitious, so that I would infer that the Tertiary relief was slight, that is under 5,000 feet and probably much less than this, although there is no evidence to warrant precision of statement.

On the other hand, the collected floras do not furnish any traces of the characteristic vegetations of low muddy shores, although types like *Rhizophora*, *Avicennia*, *Conocarpus*, *Laguncularia*, etc., were already in existence in Eocene times as we know from their presence in the Mississippi embayment of that time, where they were undoubtedly derived from the south. I do not infer that these costal types were absent in the Tertiary flora of the Isthmus. On the contrary they must have been present; but no traces of them have been discovered except the traces of *Acrostichum* in the Culebra formation.

The bulk of the fossil plants clearly belong to the evergreen rain forests and they have the appearance of having been washed into the basins of sedimentation by streams. None of the lithologic specimens that I have seen from the Isthmus indicate autochonous swamp deposits either of coastal or valley situations and I picture the flora as one of a humid tropical character covering a country of low hills. This is of necessity a tentative conclusion and perhaps even such general deductions are unwarranted because of the very limited data with which I have had to deal.

FLORA OF THE CANAL ZONE.

Arecales:

Arecaceae—

Palmoxylon palmacites (Sprengel) Stenzel.

Urticales:

Moraceae—

Ficus culebrensis, new species.

Ranales:

Anonaceae—

Guatteria culebrensis, new species.

Myristicaceae—

Myristicophyllum panamense, new species.

Rosales:

Leguminosae—

Taenioxylon multiradiatum Felix.

Inga oligocaenica, new species.

Cassia culebrensis, new species.

Geraniales:
  Malpighiaceae—
    Hiræa oligocaenica, new species.
    Banisteria praenuntia, new species.
  Euphorbiaceae—
    Hieronymia lehmanni Engelhardt?
Sapindales:
  Sapindaceae—
    Schmidelia bejucensis, new species.
Thymeleales:
  Lauraceae—
    Mespilodaphne culebrensis, new species.
Myrtales:
  Myrtaceae—
    Calyptranthes gatunensis, new species.
  Melastomataceae—
    Melastomites miconioides, new species.
Ebenales:
  Ebenaceae—
    Diospyros macdonaldi, new species.
Rubiales:
  Rubiaceae—
    Rondeletia goldmani, new species.
    Rubiacites ixoreoides, new species.
Fern fragments of Acrostichum.
Palm rays.

SYSTEMATIC PALEOBOTANY.

PTERIDOPHYTA.

Order FILICALES.

FERN FRAGMENTS OF ACROSTICHUM.

The material from the Culebra formation, one-fourth mile south of Empire Bridge, contains several obscure fragments of large simple fern pinnules with reticulate venation strongly suggestive of Acrostichum, but too incomplete for identification. The genus now principally represented by the cosmopolitan tropical tidal marsh species *Acrostichum aureum* is abundant in the Eocene and Oligocene of both America and Europe, and is especially characteristic in the Jackson, Catahoula, and Vicksburg of our Gulf States.

SPERMATOPHYTA.

Order ARECALES.

Family ARECACEAE.

PALM RAYS.

The broken rays of apparently two species of palms occur sparingly in the Culebra formation at the locality one-fourth mile south of Empire Bridge. These are too incomplete for even tentative generic determination.

Genus PALMOXYLON Schenk.

Group LUNARIA.

PALMOXYLON PALMACITES (Sprengel) Stenzel.

Plate 12, fig. 1.

Endogenites palmacites Sprengel, Commentatio, p. 39, figs. 6, 6*a*, 1828.

Fasciculites palmacites Cotta, Dendrol., pp. 49, 89, pl. 9, figs. 1, 2, 1832.—Unger in Martius, p. 59, tab. geol. 3, fig. 6, 1845.

Palmacites dubius Corda, Beitrage, p. 42, pl. 22, 1845.—Schimper, Pal Végét., vol. 2, p. 513, 1870; Handbuch, Abst. 2, p. 887, 1892.

Palmacylon tenerum Felix, Foss. Hölzer Westindiens, p. 26, pl. 4, fig. 1 1883.—Schenk in Zittel.

Palmoxylon palmacites Stengel, Foss. Palmenhölzer, p. 245, pl. 20, fig. 253 1904.

Description.—Fibro-vascular bundles small, very numerous, closel spaced, orbicular or ovate in cross section, uniformily distributed a a rule, 0.60 mm. to 0.75 mm. in diameter, and rarely, if ever, tha distance from one another. Auxiliary bundles absent.

Sclerenchyma portion excavated more or less deeply to receive th vascular portion, which is often nearly equal to it in size. Occa sionally a thin zone of sclerenchyma entirely surrounds the vascula portion. Sclerenchyma fibres small, isodiametric, greatly thickenec of nearly uniform size, about 0.035 mm. in diameter. Vessels vari able in size, ranging from 0.072 mm. to 0.18 mm. in diameter, usuall two large vessels and either none or several small vessels on the sid away from the bast in each bundle. The phloem portion in genera destroyed and represented by a disorganized cavity between the ves sels and the bast.

The ground mass of the stem consists of thin walled parenchym without intercellular spaces. The cells are small, isodiametri rounded pentagonal or hexagonal except where there are but one c two rows between closely adjacent bundles, in which case they ar

narrowly compressed and elongated parallel to the sides of the bundles. Their diameter varies from 0.035 mm. to 0.10 mm. Scattered through the stem parenchyma are darker cells which in polarized light appear to be gum cells. They are slightly larger than the parenchyma cells, being from 0.072 mm. to 0.108 mm. in diameter.

Occasional bundles are seen to be branching. These are the *fasciculi fibroductores* or Kreuzungsbündel.

This species was first recognized by Sprengel in 1828, who referred it to *Endogenites;* Cotta four years later transferred it to Fasciculites, and Corda in 1845 referred it to *Palmacites.* When Felix came to publish on the Antigua woods in 1883 he recognized this species, but in describing it under the genus *Palmoxylon* which had been proposed by Schenk only a year or two before he took the liberty of giving it the new name of *tenerum*, which under the rules of nomenclature has no standing as Stenzel recognized in print in 1904.

The specimen from Panama is small and may be from near the periphery of a stem, although in the group *Lunaria* there is little difference between the central and peripheral regions. In the size, outline, and crowding of the fibrovascular bundles as well as in the character of the parenchyma of the groundmass the present species greatly resembles *Palmoxylon integrum* described by Felix[1] from Cuba and considered by Stenzel[2] as merely a variety of the Antiguan species *Palmoxylon antiguense* (Unger) Felix.[3] It differs from that species in altogether lacking the numerous auxiliary sclerenchyma bundles which are so well marked in *Palmoxylon integrum.* A further difference is the presence of gum or mucilage cells which are fairly numerous in the Panama specimen of *Palmoxylon palmacites* and which might upon a merely superficial examination be mistaken for auxiliary sclerenchyma bundles. Among the Oligocene species of *Palmoxylon* from the southern United States *Palmoxylon mississippense* Stenzel[4] is very similar to the present species.

Other described fossil species which show more or less resemblances are *Palmoxylon stellatum*, *aschersoni*, *variabile*, and *ceylanicum.* The nearest affinity among recent palms is not determinable in the present state of our knowledge of the anatomy of the latter. The present type of structure is commonly known as the Cocos-like type.

For some unknown reason the upper Eocene and lower Oligocene in southeastern North America abounds in silicified palm wood. Palm leaves are often very abundant in the Wilcox and Claiborne Eocene and in the Apalachicola Oligocene; but all of the petrified

[1] Felix, Foss. Hölz. Westindiens, p. 24, pl. 5, fig. 2, 1883.
[2] Stenzel, Foss. Palmenhölzer, p. 154, pl. 1, figs. 1–10, 1904.
[3] Felix, Foss. Hölz. Westindiens, p. 22, pl. 4, fig. 5.
[4] Stenzel, Foss. Palmenhölzer, p. 248, pl. 21, figs. 254–265.

palm wood in our Gulf region is confined to the Jackson or Vicksburg groups.

The island of Antigua, celebrated for at least a century for its petrified woods, has furnished at least seven species of petrified palms, five of which were known to Unger as early as 1850, and one was figured by Witham in 1833. These also are of Oligocene age. There are two additional Oligocene species described from the West Indies without definite information as to exact locality, and there is also a species from Trinidad and another from Cuba. The Oligocene species at present known from the southern United States are seven in number, four of which have not been found outside of that region, while one or possibly two are common to Antigua, and a third has been reported by Felix from Southern Mexico.

Occurrence.—Cucuracha formation, green clays, Gaillard Cut (loc. 6586). Collected by D. F. MacDonald.

Collection.—U. S. National Museum. Cat. No. 35310.

Order URTICALES.

Family MORACEAE.

Genus FICUS Linnaeus.

FICUS CULEBRENSIS, new species.

Plate 13, fig. 1.

Description.—Leaves of relatively small size, broadly oblong-lanceolate in general outline, apex acute but not extended or cuspidate. Base bluntly pointed. Margins evenly rounded. Texture coriaceous. Length about 8 cm. Maximum width, in the middle part of the leaf, about 2.15 cm. Petiole short, stout, and curved. Midrib stout and prominent on the under surface of the leaf. Secondaries thin, very numerous, evenly spaced, subparallel; they diverge from the midrib at wide angles averaging about 75 degrees, pursue an almost straight outward course, their ends being connected well within the margins by regular flat arches formed by their abrupt camptodrome endings. Tertiaries obsolete.

This is an especially well-marked species of the lanceolate leafed section of *Ficus*, and it may be matched by a number of still existing species found in the American tropics. Among such a large number of both existing and fossil forms detailed comparisons are not especially pertinent. Two comparisons that seem significant are the resemblance of the present form to *Ficus newtonensis* Berry of the Upper Claiborne of the Mississippi embayment and to the forms from the Sannoisian of Haering in the Tyrol which Ettingshausen[1] refers

[1] Ettingshausen, Tert. Fl. von Haering, p. 41, pl. 10, figs. 6, 8, 1853.

to *Ficus jynx* Unger, but which appear to me to be decidedly different from Unger's type.

Occurrence.—Culebra formation, upper part. East wall of the Gaillard cut just north of Canal Commission station 1760 (collected by M. I. Goldman).

Order RANALES.

Family ANONACEAE.

Genus GUATTERIA Ruiz and Pavon.

GUATTERIA CULEBRENSIS, new species.

Plate 13, fig. 2.

Description.—Leaves of large size, broadly ovate in general outline, with a narrowed slightly decurrent base and a narrowed and extended acuminate tip. Length about 20 cm. Maximum width, approximately midway between the apex and the base, between 6 cm. and 7 cm. Margins entire. Texture coriaceous. Petiole short and stout, enlarged proximad, about 2.25 cm. in length. Midrib stout and promient. Secondaries mediumly stout and prominent, about ten opposite to alternate pairs diverge from the midrib at angles ranging from 45° to 60°, sweeping upward in regular ascending subparallel curves, camptodrome in the marginal region. Tertiaries, where visible, percurrent.

The present is one of the more abundant and better preserved forms from the Canal Zone, but the large size of the leaves usually results in fragmentary specimens, the tip being almost invariably missing. The species shows great similarity with various existing forms of Anonaceae. It is very close to *Anona marcgravii* Martius of Venezuela, French and Dutch Guiana, and Brazil (Bahia and Pernambuco). It is, however, among the various species of *Guatteria* that the closest homologies are found. The latter genus contains about fifty species of shrubs and trees, exclusively American[1] and found in Mexico, Central America, tropical South America, and in the northern Andes. The fossil may be compared with a large number of the existing species, as for example *Guatteria ouregon* Dunal, a large tree of the Carribbean islands and equatorial South America. *Guatteria dolichopoda* De Candolle or *G. grandiflora* De Candolle of Central America.

The family Anonaceae contains about 700 existing species, distributed among about 48 genera, only two of which are present in North America. The family is practically confined to the Tropics,

[1] The Asiatic species of various authors are referred to the genus *Polyalthia.*

a single Australian species, and the North American genus *Asimina*, with 6 or 7 species being the only conspicuously extratropical forms. The area of maximum representation is southeastern Asia and the adjoining region of Malaysia, for while only 16 genera are confined to this region it contains over 350 species, and six additional genera (*Miliusa*, *Uvaria*, *Polyalthia*, *Oxymitra*, *Melodorum*, and *Popovia*), with a total of over 250 species have the bulk of their species in this area. Only a single genus is confined to Australia, and the bulk of the Australian species are to be regarded as migrants from the preceding area. There are upwards of 100 species and 6 peculiar genera in tropical Africa; and America has about 200 species and 10 peculiar genera. These are all confined to the Tropics, except for a species of *Anona*, which reaches the coast of peninsular Florida, and for the genus *Asimina*, with six or seven species of shrubs and small trees of the south Atlantic and Gulf States. One of these, *Asimina triloba* Dunal, is hardy as far north as New York, and has the distinction of growing the farthest distance from the Equator of any existing member of the family. The fossil record of the Anonaceae is very incomplete, only the genera *Anona* Linneaus and *Asimina* Adanson, being known with certainty. Both of these genera are present in the flora of the Wilcox group of the Mississippi embayment.

The genus *Guatteria* has not, so far as I know, been heretofore found fossil, except for a doubtful species described by Hollick from the Upper Gretaceous of Marthas Vineyard and Long Island. The genus *Uvaria* Linnaeus has a Pliocene and three Pleistocene species on the Island of Java, and the genera *Melodorum* Dunal and *Mitrephora* Blume are both represented in the Pleistocene of that island.

The genus *Anona* has from fifteen to twenty fossil species, five of which are also represented by seeds. The oldest is a species described from the Dakota sandstone. There is a second species in the late Cretaceous or Early Eocene of the Rocky Mountain province. The flora of the Wilcox affords a glimpse into the true stage of evolution of Tertiary floras in that expanded belt of the American equatorial region which was the center of radiation of so many recent types. There were three exceedingly well-marked species of Anona along the Wilcox coast and their leaves are very common at some localities, although no seeds have as yet been discovered. I assume that these Wilcox forms had habits similar to those of the majority of the existing species, exemplified by our Florida *Anona glabra* Linnaeus, or pond apple, which frequents shallow fresh-water swamps, low shady hammocks, or stream borders near the coast. Other species occur in the low coppice association or on edges of brackish swamps on the Bahamas. The cultivated species, as, for example, the American *Anona reticulata* Linnaeus, which is planted in Guam, often

spreads naturally along the inner beaches, while attempts to introduce others of the most highly esteemed American species in the Orient have failed. From its prevalence among the existing species the habit of growing in wet, shaded soils is evidently an old one, and since the Wilcox *Anonas* are associated with a strand flora the assumption that they grew on the inner beaches or the shaded and more swampy edges of lagoons possesses every degree of probability.

In the pipe clays of Alum Bay which were contemporaneous with the Wilcox there are two species of *Anona*, and Engelhardt has described two species from the Eocene or Oligocene of Chili. The Oligocene record shows a species in France and a second in Saxony. In the Miocene there are two species each in England, Styria, and Croatia, and one each in Bohemia, Colorado, and Transylvania. There is one each in the Pliocene of France and Italy, showing how modern was their extinction in the south of Europe.

The genus *Asimina* has only four or five recorded fossil species. These are all American except for a form from the Pliocene of Italy which has been referred to this genus, although I suspect that it represents *Anona*, since *Asimina* appears to have originated and been confined to the Western Hemisphere. The oldest known species is based on foliage which is found in the basal Eocene of the Rocky Mountains (Denver formation) and of the embayment (Midway Group). There is a single species based on a seed from the basal Wilcox and no other records except a form close to the modern from the late Miocene of New Jersey (Bridgeton sandstone) and the occurrence of the existing *Asimina triloba* Dunal in the interglacial beds of the Don valley in Ontario. There are 17 existing species of Anona recorded from Central America, six of which are known from Panama. Hemsley records 11 species of *Guatteria* from Central America, at least two of which occur in Panama.

Occurrence.—Culebra formation, upper part. East wall of Gaillard Cut just north of Canal Commission station 1760 (collected by M. I. Goldman). Gatun formation. Gatun borrow pits (collected by M. I. Goldman). 7 miles northeast of Bejuca near Chame (=Caimito formation) (collected by MacDonald).

Family MYRISTICACEAE.

Genus MYRISTICOPHYLLUM Geyler.

MYRISTICOPHYLLUM PANAMENSE, new species.

Plate 13, fig. 3.

Description.—Leaves ovate or ovate lanceolate in outline with pointed apex and base, entire, evenly rounded margins, subcoriaceous in texture. Length about 9 cm. Maximum width, midway between the apex and the base, about 3.3 cm. Petiole slender, about 8 mm. long. Midrib slender. Secondaries thin, about 8 subopposite ascend-

ing subparallel pairs; they diverge from the midrib at acute angles and are subparallel with the lower lateral margins, eventually camptodrome. Tertiaries obsolete.

This species is unfortunately represented by fragmentary remains inadequate for conclusive identification. The genus *Myristica* Linnaeus contains about two score existing species, rather more than half being American tropical forms, now often segregated into several genera. Many are insular and coastal forms, Schimper recording 4 species in the Indomalayan strand flora and several species ranging eastward in the Pacific to the Fiji, Tonga, and Samoan Islands, and their fruits are recorded by both Gaudichaud and Guppy in the sea drift, although the oriental species are normally distributed by fruit pigeons (Mosley, Hemsley, Guppy).

De Candolle and Miquel both considered the foliage, especially the venation, as offering the best criteria for differentiation, but in the absence of comparative material and the incomplete character of the Panama fossil it is not possible to apply these criteria. The American Recent species number about 25, and these are mainly South American in their distribution, although the sections or genera *Virola* Aublet and *Compsoneura* De Candolle both occur in Central America.

The distribution of the Recent species in tropical America, Asia, and Africa is conclusive evidence of a Tertiary history, although this evidence is practically unknown. Geyer[1] described two forms of leaf fragments from the Miocene of Labuan (Borneo) and Engelhardt[2] a third from the Tertiary of Ecuador and Chile. The most conclusive evidence of their Tertiary radiation is furnished by the characteristic fruits described recently by the writer[3] and preserved in the wind-blown sands of the uppermost Eocene of Texas.

Occurrence.—Culebra formation (upper part). East wall of Gaillard Cut just north of Canal Commission station 1760 (collected by M. I. Goldman).

Order ROSALES.

Superfamily LEGUMINOSAE.

Genus TAENIOXYLON Felix.

TAENIOXYLON MULTIRADIATUM Felix.

Plates 14 and 15.

Taenioxylon multiradiatum Felix, Die fossilen Hölzer Westindiens Samml. palaeont. Abh., ser. 1, Heft 1, p. 11, pl. 1, figs. 10, 11; pl. 2 fig. 10, 1883.

Transverse section.—In a radial distance of 5 cm. there are no definite annual or seasonal rings. In certain zones the vessels ar

[1] Geyler, H. T., *Vega* Expedition, vol. 4, p. 498, pl. 33, figs. 3–6, 1887.

[2] Engelhardt, H., Abh. Senck. Naturf. Gesellsch., vol. 16, p. 663, pl. 6, fig. 9; pl. 7 fig. 12, 1891; vol. 19, p. 13, pl. 1, fig. 21, 1895.

[3] Berry, E. W., Amer. Journ. Sci., ser. 4, vol. 42, pp. 241–245, figs. 1–6, 1916.

larger, more generally compound, and closer together, and in other zones they are more distant, slightly smaller, and prevailingly single. No changes are observable in the other elements and there is no regular alteration of vessel rich and vessel poor areas nor any change from so-called summer to spring wood such as characterizes the trees of the temperate zone.

Vessels single or two, three, or four together in radial rows (an anomalous group of five vessels in juxtaposition is shown in the detailed drawing). Outline of single vessels elliptical, those in groups flattened on one or both sides by mutual compression; their tangential diameter ranging from 0.10 mm. to 0.14 mm.; their radial diameter ranging from 0.12 mm. to 0.16 mm., exceptionally large ones up to 0.22 mm.; their walls thick, 0.0067 mm. to 0.01 mm. in thickness, clearly showing the numerous small pits in section. Vessels frequently filled with gum. Vessels usually surrounded by one to three layers of rounded or more or less compressed thin-walled wood parenchyma, somewhat variable in amount in different parts of the stem and tending to form tangential bands. Prosenchyma very abundant, the elements polygonal, small, somewhat smaller than those of the wood parenchyma, and thick walled. Rays very numerous, one or two cells wide as seen in transverse sections, flexuous in their courses since they are bowed out around the large vessels and approach more or less in the radial intervals between vessels; from 0.10 mm. to 0.20 mm. apart, averaging nearer the former than the latter figure. The ray cells toward the ends of the rays which appear to be those usually seen in the several sections examined are not elongated radially but are nearly isodiametric and about 0.02 mm. in diameter.

Radial section.—The radial section shows the close set, fine, transversely elongated pits of the vessels which have simple perforations. The wood parenchyma is septate, the cells being about 3½ times as long as wide with large simple pits. The rays are of variable height, from 9 to 17 cells. They are seen in radial view to consist of a central series of radially elongated cells with numerous fine simple pits, above and below which is a series of longitudinally elongated cells, beyond which are one or two rows of isodiametric cells which are regularly hexagonal in this view.

Tangential section.—The tangential section shows the uniform close set fine pitting on all the walls of the vessels, the relative short length and the large simple pits of the adjoining septate wood parenchyma. The rays are seen to be very numerous, and separated by but few rows of flexuous prosenchyma; they are lenticular in outline and of variable height, one or two rays of terminal cells (those which are hexagonal in outline in the radial view) are single; then come one to three biseriate rows (those longitudinally elongated in the

radial view); toward the median region the rays are three or four cells broad (the radially elongated cells in the radial view).

Felix states that in the Antigua material the rays were usually biseriate, while uniseriate and triseriate rays were rare. I do not know the extent of his material, but in the case of that from Panama I had but few radial sections cut. Ray cells frequently filled to a greater or less degree with gum.

Remarks.—Fragments of the wood of this species are very common in the collections from Panama, but a good deal was rather badly decayed before petrification. That which has formed the chief basis for the foregoing description and all of the photographs and drawings is beautifully preserved. The species is clearly identical with the type, as very insufficiently described and illustrated by Felix. One highly ferruginized and fairly well preserved quadrant of a trunk indicates a large tree, with a diameter of at least 25 cm.

The genus *Taenioxylon* was established by Felix in 1882 with *T. varians* from Antigua as the type. He has since described 7 additional species including 2 additional from Antigua, 1 from southern Brazil, 1 from East Indies, 1 from Philippines, 1 from Caucasus, and 1 from the Swabian Alps. All are of Tertiary age and show resemblances to various members of the 3 Leguminous families Caesalpiniaceae, Miomosaceae, and Papilionaceae. Felix considers the present species to be a member of the Papilionaceae, and it agrees entirely with Solereders account of the anatomy of this family. The two kinds of ray cells described have, according to Saupe, been shown to occur in the following tribes in this family, namely the Podalyrieae, Genisteae, Galegeae, Hedysareae, and Sophoreae. Without much recent comparative material, which is unavailable, it is impossible to allocate the present species more definitely within the extensive family.

Occurrences.—Bohio formation, middle Bohio Ridge (poorly preserved) quadrant of a large trunk indicating a tree with trunk at least 25 cm. in diameter. Cucuracha formation, upper part. Green clays of Gaillard Cut (locality 6845) Oligocene limestone. Orbitoidal limestone, 2 miles north of David (locality 6523) (all above collected by D. F. MacDonald). Culebra formation, upper part. Near top of big slide, just north of Culebra. Collected by M. C. Goldman (figured material).

Collections.—U. S. National Museum, Johns Hopkins University.

Family MIMOSACEAE.

Genus INGA Willdenow.

INGA OLIGOCAENICA, new species.

Plate 16, fig. 2.

Description.—Leaflets rather above medium size, elliptical-oval and very inequilateral in general outline. Apex abruptly acute, n

xtended. Base very inequilateral, truncate or ascending on one ide and wide and cordate on the other. Margins entire, full. Tex- ure subcoriaceous. Length about 8 cm. or 9 cm. Maximum width, t or slightly above the middle, about 4 cm. Petiolule curved, short nd stout, about 3 mm. long. Midrib stout, greatly curved. Sec- ndaries thin, five or six pairs, angles of divergence and courses arious, all ultimately camptodrome; lower pair opposite, from the op of petiolule; they diverge from the midrib at angles of about 45 legrees, curving slightly outward and then ascending, parallel with he respective margins; the one in the narrow side of the lamina rches along the margin in a brochiodrome manner; the one in the vide side of the lamina sends off on the outside a series of regularly paced camptodrome tertiaries. Tertiary venation for the most art obsolete.

This characteristic species may be compared with *Inga densiflora* Bentham,[1] *Inga edulis* Martius.[2] *Inga marginata* Willdenow,[3] or *Inga peciosa* Spruce[4] and with various other of the larger-leafed species of Inga in the American Tropics to which region the 212 of its xisting species of shrubs and trees are confined. It may also be ompared with a number of tropical American species of *Cassia*, as, or example, *Cassia ruseifolia* Jacquin.

About fifteen fossil species have been referred to *Inga*. These nclude three from the Upper Cretaceous, two European, and one North American. There are also two or three species in the Oligo- ene of Europe, one in the Pliocene of Bolivia, two in the Tertiary f Ecuador, and one in the Tertiary of Colombia, four well-marked pecies in the Lower Eocene of the Mississippi embayment (Wilcox Group) and one in the middle Eocene of that region (Claiborne Group). The Panama species is not especially close to any of the oregoing. It is nearest, however, to *Inga latifolia*, described by Engelhardt[5] from the Tertiary of Ecuador, differing in its broader orm and more inequilateral base.

Pittier records 14 existing species of *Inga*, from Panama.[6] Hems- ley lists 35 species in his flora of Central America, or which number 8 are recorded from Panama.

Occurrence.—Lower part of Culebra beds one-fourth mile south of Empire Bridge. (Collected by D. F. MacDonald.) U.S.G.S. 6837.

Type.—Cat. No. 35311, U.S.N.M.

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[1] Bentham, Trans. Linn. Soc. Lond., vol. 30, p. 617, 1875 (Peru).
[2] Martius, Flora, vol. 20, Beibl., p. 113, 1837 (Brazil).
[3] Willdenow, Sp. Pl., vol. 4, p. 1015, 1806 (Venezuela).
[4] Spruce, in Bentham, Trans. Linn. Soc. Lond., vol. 30, p. 620 (Brazil).
[5] Engelhardt, H., Abh. Senck. Naturfor. Gesell., vol. 19, 1895, p. 20, pl. 2, figs. 11, 12.
[6] Pittier, H., Cont. U. S. Natl. Herb., vol. 18, pt. 5, pp. 218–223, 1916.

Family CAESALPINIACEAE.

Genus CASSIA Linnaeus.

CASSIA CULEBRENSIS, new species.

Plate 16, fig. 1.

Description.—Leaves obviously pinnately compound. Leaflets ovate, slightly inequilateral and falcate, with an obliquely acuminate, practically equilateral tip, and an acuminate markedly inequilateral base. Length about 6.25 cm. Maximum width, about midway between the apex and the base, 2.75 cm.; one side of the lamina 15 mm. wide, the other 12.5 mm. wide. Texture mediumly coriaceous. Petiolule reduced to a thickened proximal part of the midrib extending but 1 mm. below the point of junction of one margin and about 2.5 mm. below the point of junction of the opposite margin. Margins entire, evenly rounded and full. Midrib relatively thin, not prominent, curved. Secondaries thin, numerous, about 10 subopposite to alternate pairs; they diverge from the midrib at wide angles, about 70° in the middle part of the leaflet, are nearly straight regularly spaced and subparallel in their outward course for two-thirds of the distance to the margin where the principal ones fork to join in rounded arches the similar branches of adjacent secondaries; the secondaries in the apical and basal portions of the leaflet are regularly camptodrome; those toward the tip of the leaflet more closely spaced. Marginal tertiaries camptodrome, internal tertiaries mostly obsolete.

This type in its general form and the character of its base and petiolule indicates that it is a leaflet of a pinnate leguminous leaf. Its general appearance suggests comparisons with the genera *Sweetia*, *Myrocarpus*, *Toluifera*, *Cassia*, and *Sophora*—the first three confined to tropical South America and the last two cosmopolitan in the existing flora. While the evidence is not conclusive, I prefer to consider it more closely allied to *Cassia* than to the other genera mentioned, particularly as the venation characters are such as I have considered referable to *Cassia* in my studies of the fossil floras of the southern United States. No species related to the Panama form is known from the Oligocene of the United States.

The modern species of *Cassia* are very numerous, upwards of 400 having been described. They comprise herbs, shrubs, and trees of varied habitats in the warmer parts of both hemispheres, particularly tropical America. The fossil species are also numerous and the generic history goes back to near the base of the Upper Cretaceous. The genus has been continuously represented in the warmer parts of

America from the time of deposition of the Tuscaloosa sediments of Alabama to the present.

Occurrence.—Culebra formation, lower part, one-fourth mile south of Empire Bridge (collected by D. F. MacDonald) U.S.G.S. 6837:

Type.—Cat. No. 35312, U.S.N.M.

Order GERANIALES.

Family MALPIGHIACEAE.

Genus HIRAEA Jacquin.

HIRAEA OLIGOCAENICA, new species.

Plate 17, fig. 1.

Description.—Leaves relatively large, ovate-lanceolate in outline, falcate, with an equally cuneatly pointed apex and base. Margins entire, evenly curved. Texture subcoriaceous. Length about 9.5 cm. Maximum width, at or somewhat below the middle, about 3.5 cm. Petiole short, stout, about 3 mm. in length. Midrib stout, flexuous. Secondaries thin, regularly spaced, about 9 pairs, prevailingly alternate; they diverge from the midrib at angles of about 45° and sweep upward in regular subparallel slight curves, and are camptodrome in the marginal region. Tertiaries obsolete.

This genus, which has well characterized leaves, has seldom been recognized in the fossil state. One species[1] is not uncommon in the lower Eocene of the Mississippi embayment, and Ettingshausen[2] has recorded, but not described, a second species from the Ypresian of Alum Bay, England.

The existing species number between 25 and 30 and are exclusively American, ranging from Mexico and the Antilles throughout Central and northern South America to the Peruvian tropics.

The present fossil species is not unlike *Hiraea wilcoxiana* Berry[3] from the lower Eocene of Tennessee and is closely comparable with the existing *Hiraea chrysophylla* Jussieu of the northern coastal region of South America.

Occurrence.—Caimito formation 7 miles northeast of Bejuca (U.S.G.S. station 6840). Collected by D. F. MacDonald.

Type.—Cat. No. 35313, U.S.N.M.

Genus BANISTERIA Linnaeus.

BANISTERIA PRAENUNTIA, new species.

Plate 17, fig. 2.

Description.—Leaves of medium size, broadly ovate in general outline, with an abruptly acuminate tip and a broad rounded or cuneate base. Length about 8 cm. Maximum width, at or slightly above the

[1] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 257, pl. 57, fig. 8; pl. 109, fig. 6, 1916.

[2] Ettingshausen, C. von, Roy. Soc. London Proc., vol. 30, p. 235, 1880.

[3] U. S. Geol. Survey Prof. Paper 91, p. 257.

middle, about 5 cm. Margins entire, full and rather evenly rounded. Petiolar character unknown. Midrib of medium size, uncharacteristic. Secondaries thin, seven or eight opposite to alternate pairs diverge from the midrib at regular intervals at angles varying from 45° in the upper part of the leaf to 55° in the basal part; they ascend in slight but subparallel curves increasing in intensity as they proceed toward the margins with which they become subparallel and eventually camptodrome. Tertiaries thin, mostly obsolete. Leaf substance thin but apparently of a somewhat coriaceous texture.

The present species receives its name from its supposed praenuntial relationship to the existing *Banisteria sinemariensis* De Candolle, a form ranging from the West Indies to Brazil and whose somewhat variable leaves may be exactly matched by the fossil.

The genus contains upward of eighty existing species, mostly climbing shrubs, confined to the American tropics and largely developed in northern South America. Its geological history goes back to the Lower Eocene, a species having been described by Watelet from the Ypresian of the Paris basin and four homotaxial species, one based on seeds, having been described by the writer from the Wilcox group of the Mississippi embayment in Western Tennessee and Kentucky. Several additional fossil species have been described from the European Tertiary, from all of which the Panama fossil is conspicuously different, its major differential character being its relatively short and broad outline.

A species based upon fruits has been described by Engelhardt[1] from the Tertiary of Ecuador.

There are 5 species of *Banisteria* recorded by Hemsley from Central America, 3 of these in Panama, *B. billbergiana* Beurling on the seashore of the island of Manzañillo. Two additional Panama species of *Banisteria* are referred to the allied genus *Heteropterys* Kunth by Hemsley.

Occurrence.—Culebra formation. West wall of Gaillard Cut below Miraflores locks (collected by M. I. Goldman). Culebra formation (lower). West wall of Canal opposite Culebra Railroad station (Collected by D. F. MacDonald).

Family EUPHORBIACEAE.

Genus HIERONYMIA Allem.

HIERONYMIA LEHMANNI Engelhardt (?).

Plate 16, fig. 3.

Hieronymia lehmanni Engelhardt, Über neue Tertiärpflanzen Süd-Amerikas, Abh. Senck. Naturf. Gesell., vol. 19, p. 11, pl. 2, figs. 1, 2, 1895.

Description.—Leaves broadly elliptical or somewhat deltoid and inequilateral in outline, with a shortly acuminate tip and broadly

[1] Engelhardt, H., Über neue Tertiärpflanzen Süd-Amerikas, Abh. Senck. Naturf. Gesellsch., vol. 19, p. 14, pl. 2, figs. 18, 19, 1895.

rounded full lower lateral margins and a very wide, somewhat obliquely truncated base. Length about 12 cm. Maximum width, in the lower half of the leaf, about 10 cm. Margins entire, full, and rounded. Texture thin but coriaceous. Midrib stout, curved, prominent on the lower surface of the leaf. Secondaries stout, 10 or 11 irregularly spaced pairs, prominent on the lower surface of the leaf; they diverge from the midrib at wide angles which become more acute in the apical part of the leaf, those on the narrower side are more ascending and somewhat straighter than those on the wide side, all are conspicuously camptodrome at some distance from the margin. Tertiaries thin, mostly percurrent. Areolation of small, isodiametric polygonal meshes, well marked on the under side of the leaf.

This large leaf is unfortunately represented by fragmentary material from a single locality in the Caimito formation. In some respects its characters suggest a broad *Ficus*, but it seems clearly identical with the species described by Engelhardt[1] in 1895 from the Tertiary of Ecuador. I have, however, queried the determination because of the broken character of the Panama material. In the illustration I have reconstructed a leaf from a combination of the Panama material with the more complete specimens figured by Engelhardt from Ecuador. The two largest fragments from Panama are indicated on the drawing by tinting. It is unfortunate for purposes of correlation that the present determination can not be conclusive, although in view of other similarities shown between the Oligocene plants of Panama and those from the Tertiary of Ecuador, I am disposed to regard the present determination as fairly satisfactory.

The genus *Hieronymia* comprises about a dozen existing species of shrubs and trees confined to tropical America and rather widely distributed from Mexico to Brazil as well as in the West Indies.

Occurrence.—Caimito formation, 7 miles northeast of Bejuca (U.S.G.S. station No. 6840). (Collected by D. F. MacDonald.)

Collection.—U. S. National Museum, Cat. No. 35314.

Order SAPINDALES.

Family SAPINDACEAE.

Genus SCHMIDELIA Linnaeus.

SCHMIDELIA BEJUCENSIS, new species.

Plate 17, fig. 4.

Description.—Leaf or leaflet elongate elliptic in outline, inequilateral. Apex and tip equally and bluntly pointed inequilateral. Margins entire. Texture coriaceous. Length about 11 cm. Maxi-

[1] Über neue Tertiärpflanzen Süd-Amerikas, vol. 19, p. 11, 1895.

mum width, midway between the apex and the base, about 4.5 cm. Width on one side of the midrib 21.5 mm., on opposite side 24 mm. Petiole missing. Midrib flexuous, stout, and prominent. Secondaries stout, regularly spaced, mostly immersed, about 7 alternate pairs diverge from the midrib at angles of about 50°, curving upward subparallel and camptodrome in the marginal region. Tertiaries mostly obsolete, a few percurrent ones seen.

This large and striking leaf is referred to the sapindaceous genus *Schmidelia*, which comprises about 100 existing species of the equatorial regions of both hemispheres with unifoliate or palmately compound leaves. About half of the species are American where they are confined to the Antilles, Central, and tropical South America. They are sometimes referred to the genus *Allophylus* Linnaeus (as by Radlkofer) and with the exception of this genus all of the members of the tribe Thouinieae are confined to America. Fossil representatives have been unknown except for the petrified wood from the Oligocene of the island of Antigua which Felix described as Schmideliopsis.[1]

Occurrence.—Culebra formation. East wall of Gaillard Cut just north of station 1760 (collected by M. I. Goldman).

Caimito formation, 7 miles northeast of Bejuca (U.S.G.S. 6840). Collected by D. F. MacDonald.)

Type.—Cat. No. 35315, U.S.N.M.

Order THYMELEALES.

Family LAURACEAE.

Genus MESPILODAPHNE Nees.

MESPILODAPHNE CULEBRENSIS, new species.

Plate 17, fig. 3.

Description.—Leaves lanceolate-falcate in general outline, with acuminate apex and base. Margins entire. Texture subcoriaceous. Length about 10 cm. Maximum width, in the middle part of the leaf, about 2.5 cm. Petiole missing. Midrib stout, curved, prominent on the under surface of the leaf. Secondaries stout, remote, regularly spaced, nine or ten subopposite to alternate pairs, they diverge from the midrib at angles of about 65 degrees and are conspicuously camptodrome close to the margins. Tertiaries obscured by the poor preservation of the material.

The present species resembles numerous existing and fossil species of Lauraceae, from all of which, however, it appears distinct. It is similar to *Mespilodaphne columbiana* Berry of the Upper Claiborne of the Mississippi embayment, but is a stouter, more falcate, shorter and less acuminate form.

[1] Felix, J., Die fossile Hölzer Westindiens, p. 16, pl. 2, figs. 6, 8. 1883.

The modern species of *Mespilodaphne* are numerous, inhabiting Africa and tropical America, and are often united with *Oreodaphne* and *Strychnodaphne* to form the composite genus *Ocotea* of Aublet. Their fossil history is almost entirely lost in the multitude of species that have been referred to the form genera *Laurus* and *Laurophyllum*. *Mespilodaphne* is abundant and varied throughout the Eocene and Oligocene of the Mississippi embayment area.

Occurrence.—Culebra formation, upper part. East wall of the Gaillard Cut just north of Canal Zone station 1760. (Collected by M. I. Goldman.)

Order MYRTALES.

Family MYRTACEAE.

Genus CALYPTRANTHES Swartz.

CALYPTRANTHES GATUNENSIS, new species.

Plate 18, fig. 1.

Description.—Leaves broadly oblong-elliptic in general outline, widest in the middle and tapering equally in both directions to the abruptly acute apex and base. Margins entire. Texture subcoriaceous. Length between 7 cm. and 8 cm. Maximum width between 3.5 cm. and 4 cm. Petiole missing. Midrib stout, somewhat curved, prominent on the lower surface of the leaf. Secondaries thin, very numerous, and close set, often inosculating by forking; they diverge from the midrib at angles averaging about 70 degrees, at intervals of 1 mm. to 3 mm., pursue a but slightly curved outwardly ascending course and have their ends united by an acrodrome vein on each edge of the lamina parallel with and from 1 mm. to 2 mm. within the margin. Tertiaries forming open isodiametric polygonal meshes.

The present well-marked species closely resembles the only other named fossil form *Calyptranthes eocenica* Berry from the lower Eocene of the Mississippi embayment (Wilcox Group). It may also be compared with the slightly smaller *Myrtus rectinervis* described by Saporta[1] from the Sannoisian of southeastern France.

The genus *Calyptranthes*, which is exclusively American in the existing flora, has about seventy species ranging from Mexico and the West Indies to southern Brazil. There is a strong generic likeness between the leaves of all of the species. *Calyptranthes zyzygium* De Candolle may be mentioned, among others, as a form with leaves almost exactly like the fossil. There is also a marked family resemblance to some of the existing tropical American species of *Eugenia*, and more especially *Myrcia*, *Myrcia multiflora* De Candolle from the Guianas being very similar to the present species.

[1] Saporta, Études, vol. 1, p. 251, pl. 11, fig. 5, 1863.

Hemsley records 7 existing species of *Calyptranthes* from Central America, two of which occur in Panama.

Occurrence.—Gatun formation, Gatun Borrow Pits. (Collected by M. I. Goldman.)

Family MELASTOMATACEAE.

Genus MELASTOMITES Unger.

MELASTOMITES MICONIOIDES, new species.

Plate 18, fig. 2.

Description.—Leaf oblong-elliptic in outline, of relatively small size, with an equally and bluntly pointed apex and base. Length about 6 cm. Maximum width, in the middle part, about 2.25 cm. Margins entire. Texture subcoriaceous. Petiole short and stout. Midrib stout and prominent. Lateral primaries stout, prominent, diverging from the midrib at an acute angle just above the base and acrodrome. From the disposition of the outwardly directed nervilles from the primaries it is probable that subordinate acrodrome primaries constitute an infra marginal vein on each side, but these can not be made out. Close-set subparallel nervilles run transversely between the midrib and the primaries.

This species is represented by a small amount of fragmentary material, too poor to permit definite generic determination. It is therefore, referred to the form-genus *Malastomites* proposed by Unger for generically undeterminable leaves of the Melastomataceae. While the fossil somewhat suggests the leaves of various Lauraceous genera, such as *Cinnamomum*, *Camphoromaea*, *Goeppertia*, and *Cryptocarya*, its characters are clearly those of the Melastomataceae. It particularly suggests the genus *Tibouchina* Aublet, which has upward of 200 species of shrubs and undershrubs in tropical America.

The family Melastomataceae is a relatively large one, with about 150 genera and over three thousand species. It is almost strictly tropical, although some members range southward to 40° south latitude. This great family is typically American, seven of the fifteen tribes into which it is divided being confined to tropical America, and about 2,500 of the existing species being also endemic in this region. While the geologic history of this vast assemblage of forms is practically unknown, there is no evidence to disprove the theory that it, like the allied families Combretaceae and Myrtaceae, had its origin in that most prolific region—the American tropics.

The few fossil forms that have been found, including leaves, flowers, and calices, have been referred to the form-genus *Melastomites* first proposed by Unger. A doubtfully determined species, which probably belongs to the Lauraceae, has been recorded from the U-

per Cretaceous of Westphalia. The only known Eocene species is the well-marked form present in the lower Eocene of the Mississippi embayment region (Wilcox Group.) Four Oligocene species have been described from Bohemia, Styria, and Egypt; four Miocene species from Switzerland, Prussia, and Croatia; and a Pliocene species from Italy.

Occurrence.—Culebra formation, upper part. East wall of Gaillard Cut just north of Canal Zone station 1760. (Collected by M. I. Goldman.)

Order EBENALES.

Family EBENACEAE.

Genus DISOPYROS Linnaeus.

DIOSPYROS MACDONALDI, new species.

Plate 18, figs. 4–8.

Description.—Globose berry-like fruits of small size and considerable consistency, possibly preserved in an unripe state since the flesh is stringy and with a great many tannin cells. The great abundance of these fruits in the andesitic tuffs makes it seem more probable, however, that they are mature, particularly as some are greatly flattened. The numerous elongated pendulous seeds and the amount of vascular fibers in the flesh would tend to prevent much compression in a certain number of cases. Diameter 12 to 15 mm. Flesh hard, very tanniferous, and with numerous fibers. Seeds 8 to 10 in number, oblong, elliptical, compressed, with a hard seed coat. The interior of the seeds is filled with amorphous silica and fails to show any structure. Seeds about 7.5 mm. long, averaging 3 mm. high and 1 mm. to 2 mm. thick, very unequally developed, one to three usually more or less abortive. Peduncle not preserved, nor do any of the specimens show the calyx.

These seeds are exceedingly abundant and more or less perfectly silicified, the flesh being dark brown and the seeds white, making very striking objects. They are clearly referable to *Diospyros* and so far as I know represent the only known petrified fruits of this genus, although the persistent calices are not uncommon as impressions from the Upper Cretaceous onward. The modern species have from 4 to 12 compressed seeds which tend to become less numerous with the increase in the fleshy part of the fruit, so that possibly these more consistent and prevailingly 10-seeded fossil fruits may represent an earlier stage in their evolution, although this seems doubtful since the calyx of a very large fruited form is known from the Upper Eocene of southwestern Texas.

Diospyros is cosmopolitan in the existing flora with about 18 species in the warmer regions of both hemispheres. Mostly Oriental but not uncommon in the southern United States, Antilles, and from Mexico through tropical South America. Upward of 100 fossil species are known ranging in age from the Upper Cretaceous to the present.

Occurrence.—Section near mouth of Tonosi River, in deposits of Eocene age (MacDonald).

Type.—Cat. No. 35316, U.S.N.M.

Order RUBIALES.

Family RUBIACEAE.

Genus RONDELETIA Plumier.

RONDELETIA GOLDMANI, new species.

Plate 18, fig. 3.

Description.—Leaves lanceolate in outline, somewhat falcate and inequilateral, with an equally acuminate apex and base. Length between 12 cm. and 13 cm. Maximum width, midway between the apex and the base, about 3 cm., 13.5 mm. on the concave side and 15.5 mm on the convex side. Margins entire. Texture coriaceous. Petiole short and stout, expanded proximad, about 5 mm. long. Midrib curved, stout, and prominent. Secondaries thin, numerous, subopposite to alternate, rather regularly spaced; about 15 pairs diverge from the midrib at angles of about 45° and ascend in rather flat but regular and subparallel curves and are camptodrome in the marginal region. Tertiaries obsolete.

This well-marked species is referred to the subfamily Cinchonoideae and tribe Rondeletieae and seems to indicate an Oligocene species of *Rondeletia*, a genus of shrubs and trees confined to tropical America and not heretofore found fossil. Rondeletia has about 70 existing species, a few of which occur in northern South America, but the majority are confined to the Antilles (45 species) and Central America (24 species).[1] The present species may be compared with the existing *Rondeletia racemosa* Swartz of Jamaica, and with other Antillean and Central American forms. More remote comparisons may be made with certain species of *Psychotria*, as, for example, *Psychotria barbiflora* De Candolle of Brazil, and with the genus *Tapiria* Jussieu of the Anacardiaceae, a fossil species of which, *Tapiria lanceolata*, has been described by Engelhardt[2] from the Tertiary of Ecua

[1] Britton records 35 species from Cuba. Bull. Torrey Bot. Club, vol. 44, pp. 20–30, 191

[2] Engelhardt, H., Über neue Tertiärpflanzen Süd-Amerikas, Abh. Senck. Naturf. Gesel vol. 19, p. 15, pl. 9, fig. 4, 1895.

lor. Another fossil species somewhat resembling the Panama form s *Cinchonidium multinerve* described by Ettingshausen[1] from the Tertiary of Priesen, Bohemia.

Named in honor of Dr. Marcus I. Goldman, who collected it while a Fellow at the Johns Hopkins University.

Occurrence.—Gatun formation, Gatun Borrow Pits. (Collected by M. I. Goldman.)

Genus RUBIACITES Weber.

RUBIACITES IXOREOIDES, new species.

Plate 18, figs. 9–12.

Description.—Fruit bilocular, indehiscent or tardily dehiscent, igneous, capsular-like. Form a prolate spheroid 2.7 cm. long and 2 cm. in diameter. The surface roughened by small tuberculations and pits. Walls about 2 mm. thick. Median partition thin. Seeds one in each cell, suspended, elliptical in both transverse and longitudinal sections, compressed along the central partition. Surface striate. Endosperm not ruminating. One seed is more fully developed than the other. The larger is about 2 cm. long, 1.4 cm. wide and 9 mm. thick.

This well marked form is unfortunately represented by but a single specimen which however shows most of the cavity occupied by the fruit, the two contained seeds partially petrified and the lignified wall and part of the partition. The accompanying illustrations show the external appearance of the fruit (fig. 9) and a side view showing the relative development of the two seeds (fig. 10). Figure 12 shows a lignified end of the fruit with the median partition and figure 11 is a side view with the smaller seed in front and the larger forming the background. So far as I know nothing like it has previously been found fossil.

There seems to be no question but that the present fruit represents some Oligocene species of Rubiaceae and it is consequently referred to the form-genus *Rubiacites* proposed by Weber, although probably not congeneric with the previously described fossil species of *Rubiacites*. The fruits of this large family exhibit considerable variety being either capsular, achene-like or drupaceous. Without a much larger amount of recent comparative material than is available it is not possible to definitely fix the botanical relation of the present species which, however, appears to be referable to the tribe Ixoreae or the Psychotrieae. The specific name chosen suggests a resemblance to the fruits of *Ixora* Linnaeus, a genus with over 100 species of

[1] Ettingshausen, C. von, Die Fossile Flora des Tertiär-Beckens von Bilin, Theil 2, p. 208, t. 36, fig. 5, 1868.

shrubs and small trees found in the tropics of both hemispheres bu chiefly Asiatic.

Occurrence.—Gatun formation. Gatun Borrow Pits. (Collected by M. I. Goldman.)

EXPLANATION OF PLATES.

PLATE 12.

Palmoxylon palmacites (Sprengel) Stenzel. Cucuracha formation.

FIG. 1. Showing abundance of fibrovascular bundles and gum cells. ×20.

PLATE 13.

FIG. 1. *Ficus culebrensis* Berry. Culebra formation.
2. *Guatteria culebrensis* Berry. Culebra formation.
3. *Myristicophyllum panamense* Berry. Culebra formation.

PLATE 14.

Taenioxylon multiradiatum Felix. Culebra formation.

FIG. 1. Transverse section. ×25.
2. Same. ×200.

PLATE 15.

Taenioxylon multiradiatum Felix. Culebra formation.

FIG. 1. Radial section. ×200.
2. Tangential section. ×200.

PLATE 16.

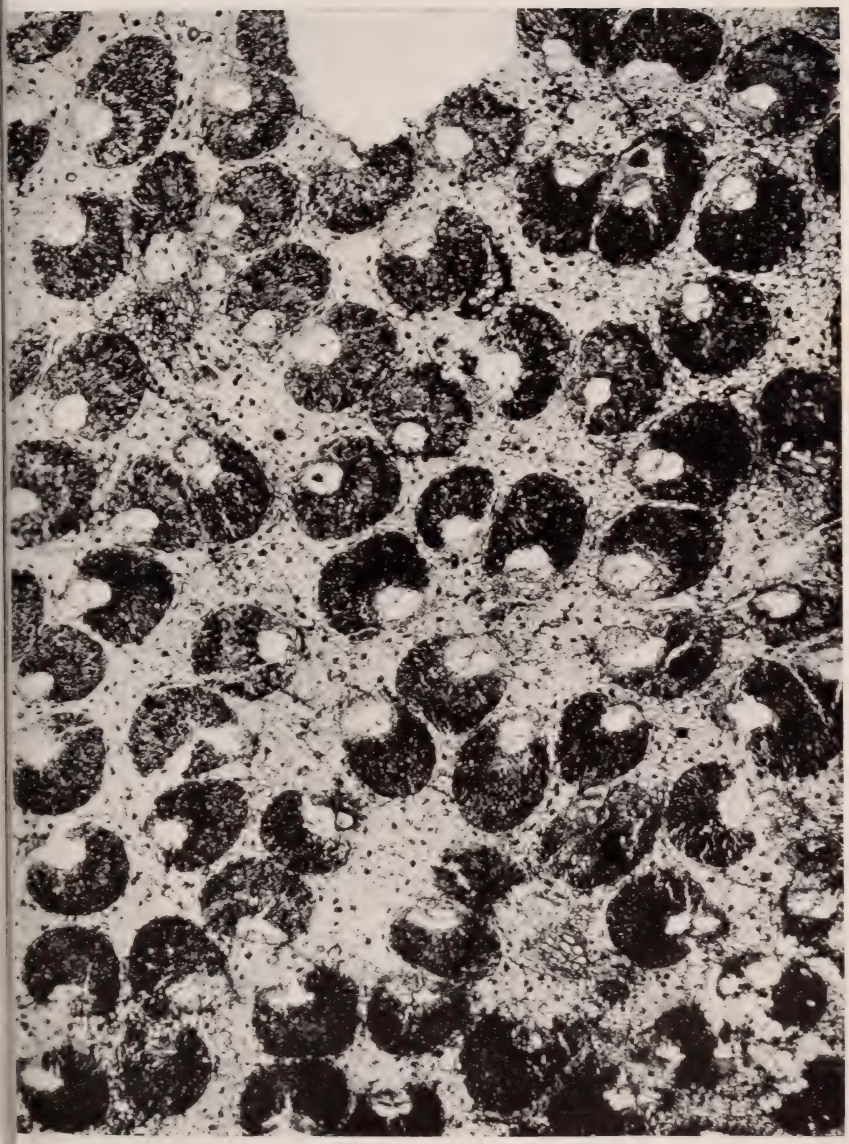
FIG. 1. *Cassia culebrensis* Berry. Culebra formation.
2. *Inga oligocaenica* Berry. Culebra formation.
3. *Hieronymia lehmanni* Engelhardt (?). Caimito formation.

PLATE 17.

FIG. 1. *Hiraea oligocaenica* Berry. Caimito formation.
2. *Banisteria praenuntia* Berry. Culebra formation.
3. *Mespilodaphne culebrensis* Berry. Culebra formation.
4. *Schmidelia bejucensis* Berry. Caimito formation.

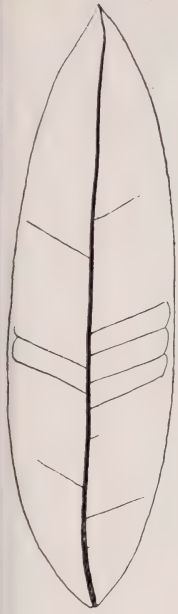
PLATE 18.

FIG. 1. *Calyptranthes gatunensis* Berry. Gatun formation.
2. *Melastomites miconioides* Berry. Culebra formation.
3. *Rondeletia goldmani* Berry. Gatun formation.
4–8. *Diospyros macdonaldi* Berry. Eocene (?).
4. Showing abundance of fruits in tuffs.
5, 7, 8. Transverse median sections of fruits.
6. Longitudinal median section of fruit.
9–12. *Rubiacites ixoreoides* Berry. Gatun formation.
9. External appearance.
10. Median longitudinal section showing unequally developed seeds.
11. Side view of seeds.
12. Lignified fragment showing end walls and partition.



PALMOXYLON PALMACITES (SPRENGEL) STENZEL.

FOR EXPLANATION OF PLATE SEE PAGE 44.



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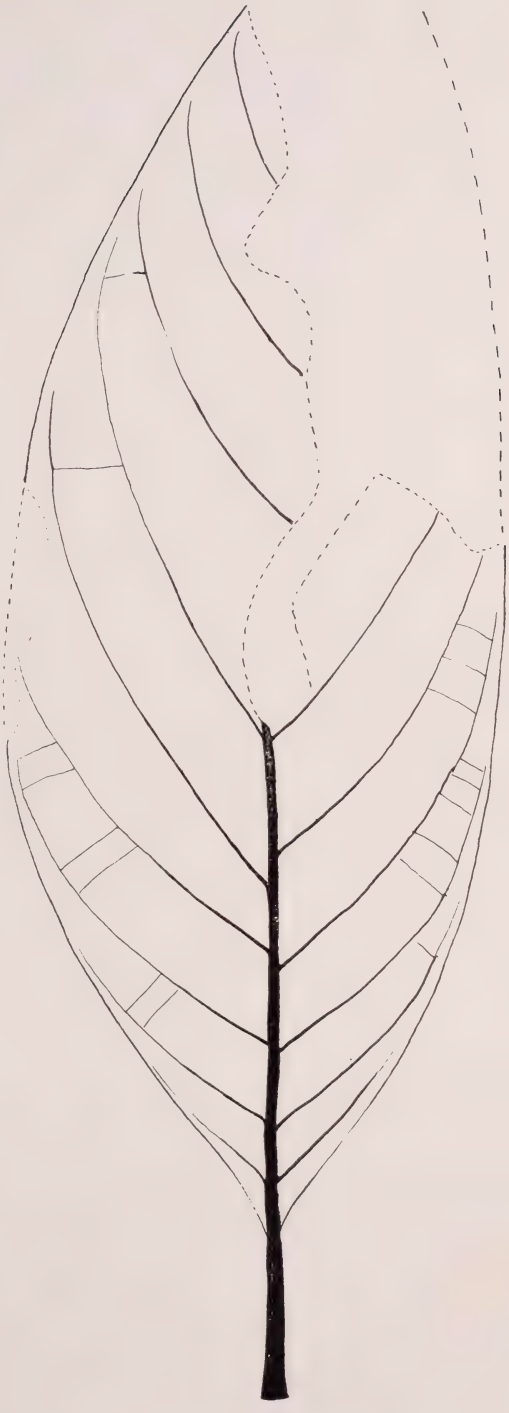

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FOSSIL DICOTYLEDONOUS LEAVES.

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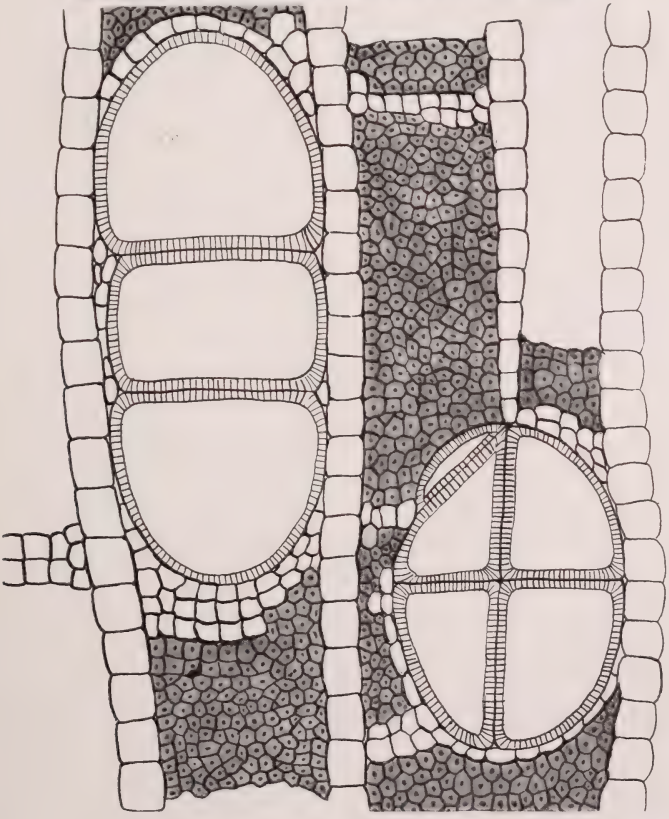

TAENIOXYLON MULTIRADIATUM FELIX.

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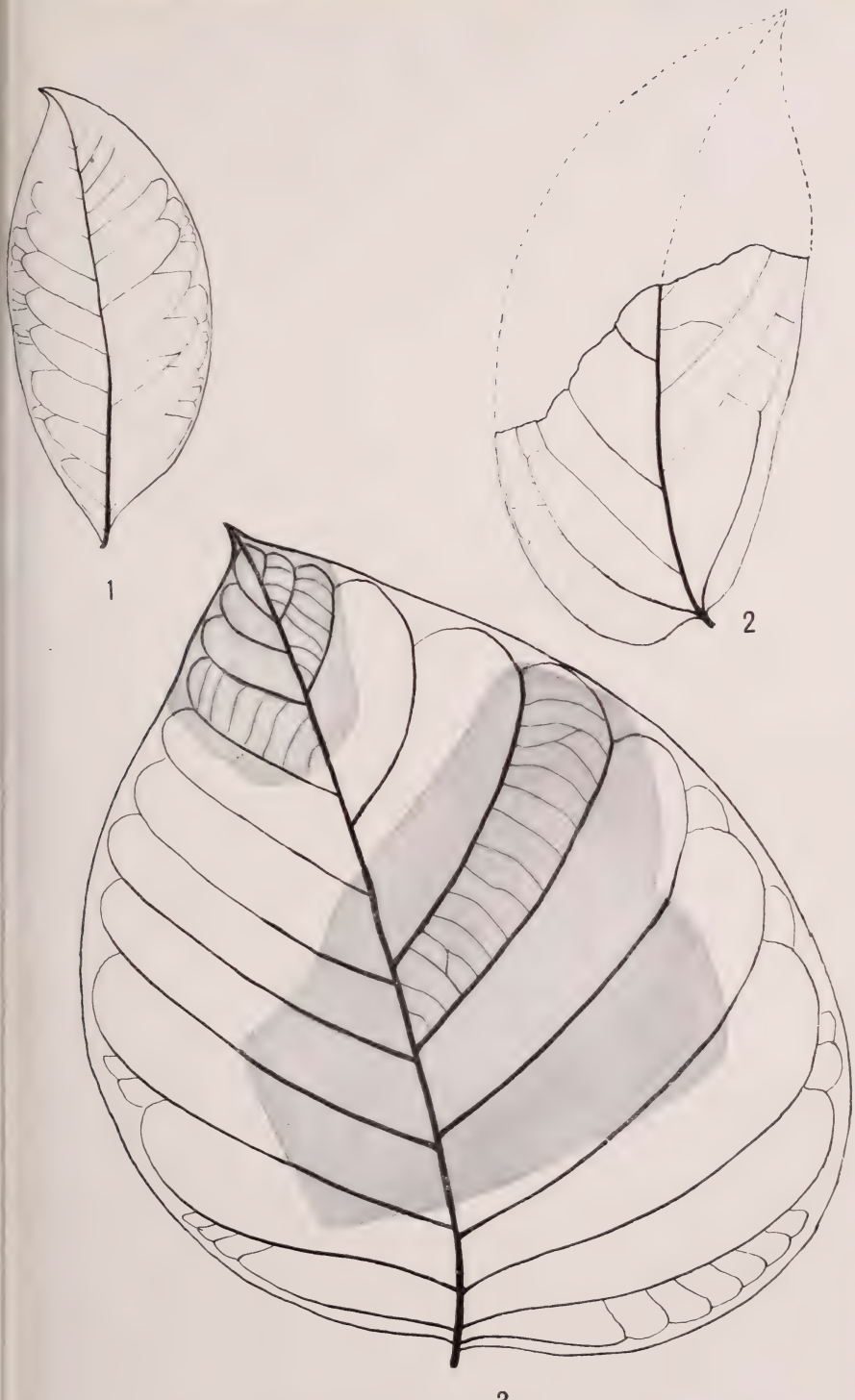

FOSSIL DICOTYLEDONOUS LEAVES.

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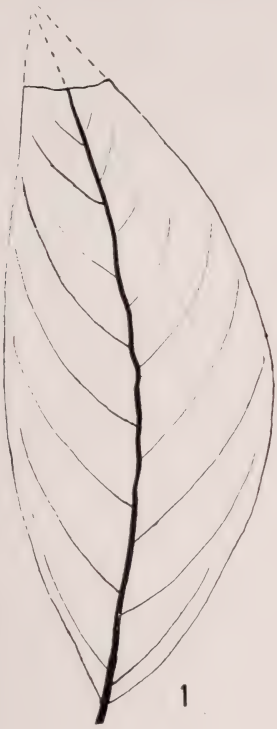

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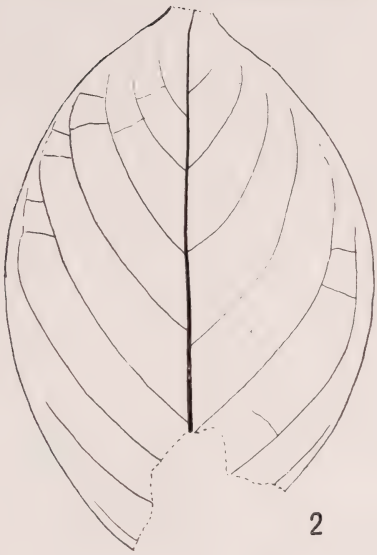

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FOSSIL DICOTYLEDONOUS LEAVES.

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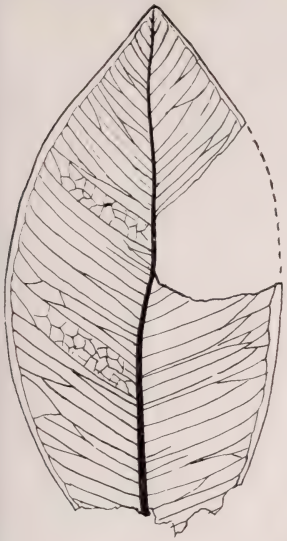

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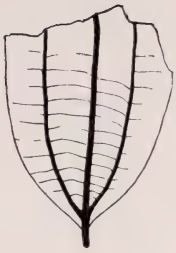

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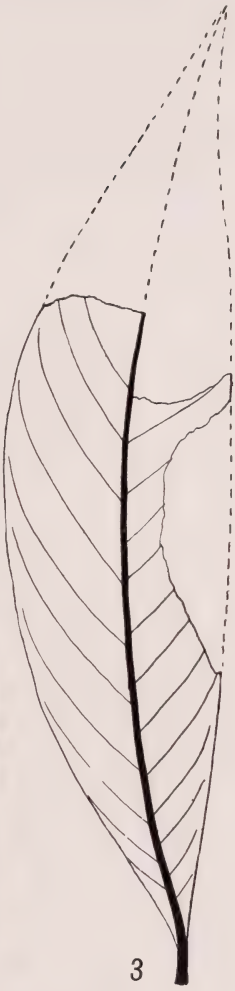

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12

FOSSIL LEAVES, FRUITS, AND SEEDS.

FOR EXPLANATION OF PLATE SEE PAGE 44.

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

THE SMALLER FOSSIL FORAMINIFERA OF THE PANAMA CANAL ZONE

By JOSEPH AUGUSTINE CUSHMAN
Of the United States Geological Survey

Extract from Bulletin 103, pages 45–87, with Plates 19–33

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1918

THE SMALLER FOSSIL FORAMINIFERA OF THE PANAMA CANAL ZONE.

By Joseph Augustine Cushman,
Of the United States Geological Survey.

INTRODUCTION.

The collection of fossil foraminifera included in this report were sent to the writer by the United States Geological Survey. It consists almost entirely of material collected by Messrs. D. F. MacDonald and T. Wayland Vaughan in 1911, to whom I am indebted for data as to the geological correlation. The names applied to the geologic formations are those used in MacDonald's "Sedimentary formations of the Panama Canal Zone, with special reference to the stratigraphic relations of the fossiliferous beds," which appears in the latter part of this volume. Where former correlation has seemed not to apply to the foraminifera, especially those of three stations, 6033*c*, 6035, and 6036*a*, discussion of the data obtained from the foraminifera is given in detail later.

The orbitoids and nummulites are both well represented in the collection, but as these require special study in connection with those of the Coastal Plain and of the West Indian region it seems advisable to treat them in a separate paper which immediately follows the present one.

The following data are given for only the stations from which foraminifera were obtained and which are recorded in this paper.

LIST OF MATERIAL.

U.S.G.S. station 6009.—Oligocene—Culebra formation (upper part).
From section in Canal cut 600 feet south of Miraflores Locks.
Dark, soft, fairly well laminated clay rock.
Few foraminifera and rather poorly preserved.

6010.—Oligocene—Culebra formation (lower part).
From section—Pedro Miguel Locks to Paraiso Bridge.
Dark, well laminated, very soft, carbonaceous clay rocks.
Foraminifera in fairly good numbers and a rather varied assortment; mostly stained black, except certain of the Miliolidae, which still keep their calcareous tests more or less in their original condition.

6012.—Oligocene—Culebra formation.

From section—west side of Gaillard Cut.

a. Dark, well laminated soft and very friable carbonaceous shale

Few foraminifera—some glauconitic, others well preserved.

c. From a lens of sandy limestone 5 feet thick.

Few foraminifera—some stained, some glauconitic, rather poorly preserved as to details.

d. From lenses of limy sandstone at base of gravel, 3 feet thick

Few foraminifera and these poorly preserved.

6015.—Oligocene—Emperador limestone.

From old quarry, one-fourth mile north of west from Empire

Cream-colored, coral limestone.

Few foraminifera.

6016.—Oligocene—Emperador limestone.

From old quarry, one-third mile north of west of Empire.

Few poorly preserved foraminifera.

6019.—Section on west side of Gaillard Cut near Las Cascadas.

a–f. Oligocene—Culebra formation.

a. Grayish, rather nodular, impure limestone.

Foraminifera few and poor.

b. Dark, well stratified, very friable, tufaceous material.

Foraminifera few and poor except *Orbitolites*, which are large and fine.

c. Grayish, well stratified, very friable, tufaceous sandstone.

Few casts of foraminifera and central portions of orbitoids.

d. Grayish-green, limy, tufaceous sandstone.

Very few foraminifera, poor specimens.

e. Thin-bedded, light gray to cream-colored, limy sandstone with some partings of light-colored clay.

orbitoids and *Orbitolites?* only.

f. Dark, very friable shales and tuffs.

Foraminifera fairly common, some well preserved, others glauconitic.

g. Oligocene—Emperador limestone.

Light gray to yellowish gray, somewhat sandy limestone.

Some orbitoids and *Orbitolites?* but little else in the way of foraminifera.

6020.—Oligocene—Culebra formation.

Same locality as 6019.

a–c. Dark-gray carbonaceous clays, friable shales and tuffs.

a. Foraminifera numerous but of few species, mostly glauconitic, at least in part.

c. A few *Orbitolites* in the coralliferous layer.

3024.—Section in railway cuts near New Frijoles.

a. Oligocene—Culebra formation.

Dark, basic, orbitoidal, tufaceous material.

Many worn central portions of Orbitoids and a very few other foraminifera poorly preserved.

3025.—Oligocene—Culebra formation (upper part).

About 200 yards south of southern end of switch at Bohio Ridge station relocated line Panama Railroad.

Contains a number of species of foraminifera but for the most part broken or poorly preserved.

3026.—Two miles south of Monte Lirio.

Somewhat coarse-grained sandstone.

Few poor specimens of foraminifera.

3029.—Section one-half mile from Camp Cotton, toward Monte Lirio, at big curve on railroad. Miocene—Gatun formation.

a. Bluish, fossiliferous argillite.

Very few foraminifera.

b. Bluish argillite.

Few foraminifera, but considerably more than in *a*.

c. Bluish, fossiliferous argillite.

Very few poor specimens of *Amphistegina*.

3030.—Railroad cut north side of Big Swamp, one and one-half miles north of Monte Lirio. Miocene—Gatun formation.

Bluish gray, argillaceous beds.

The only foraminifera consisted of a single specimen of *Triloculina*.

3031.—Section in cut one-half mile west of Camp Cotton toward Gatun. Miocene—Gatun formation.

Conglomerate bed and sandy marl 1 foot above.

A few poorly preserved specimens of *Quinqueloculina* were the only foraminifera.

3033.—Generalized section of the bluffs exposed along the Panama Railroad, relocated line, about 3,500 feet south of Gatun Railroad Station. Miocene Gatun—formation.

c. Dark-colored, marly, fossiliferous clay.

Rich in foraminifera, especially in specimens. A fair number of species, well preserved.

3035.—Vicinity of Mindi Hill. Miocene—Gatun formation.

Gray-green, fine grained sandy shell marl.

Very fine-grained material, but with numerous species and specimens of foraminifera representing an off-shore assemblage.

3036.—Monkey Hill, Mount Hope Station. Miocene—Gatun formation.

Dark-colored, fine grained, sandy clay marl.

Specimens of foraminifera numerous and well preserved, rep
resenting an off-shore assemblage comparable to 6035.

5850.—Near Mount Hope—Pleistocene.

Loose shells and marl obtained from ditch through swamp
ground about one-fourth mile from present sea beach an
about 6 to 8 feet above high tide.

Contains a few foraminifera of common shallow water, tropic
species.

The geological position of certain material from near the Atlant
end of the canal seems from the evidence of the contained forami
fera to be younger than the position previously assigned to it—t
upper Oligocene. By a reference to the table of distribution it w
be noted that the great majority of the species occurring at the st
tions in question; 6533*c*, 6035, and 6036, do not occur in the m
terial of definitely Oligocene age. In such cases as that of *Crist
laria rotulata* there is a slight difference in the specimens from the
stations and those from the Pacific side, 6010, 6012*a*, 6012*c*, but t
specimens at the latter stations were in small quantity, and the d
ferences could not be made use of, mainly from lack of a sufficie
number of specimens. In the case of *Cristellaria vaughani* th
seems to be a well-characterized species occurring at several statio
but even in it there are very minor differences. Among the spec
of *Globigerina*, the more generalized species such as *G. bulloid*
which has a very wide geological range, occur more or less constan
throughout the collections, but the strongest evidence comes fro
the last three species and *Orbulina*, which are very rarely fou
fossil, and then only in the very latest tertiary. These were w
characterized species, the specimens are very clean and complete, a
resemble a modern Globigerina ooze of considerable depth. Th
three species of *Pulvinulina* also occur nowhere but at these statio
Pulvinulina concentrica is essentially a recent species and *P. r
nardii* is characteristic of modern *Globigerina* ooze. *Sigmoili
tenus* and *S. asperula* are also speces of recent *Globigerina* ooze f
moderate depths. On the other hand, the lack of certain things s
also significant. *Amphistegina*, which occurs more or less regula
in the other portion of the material, is entirely wanting in the th
Pacific stations, 6033*c*, 6035, and 6036. *Polystomella* also does n
occur. Both the last two genera are very characteristic of e
coastal plain Oligocene of the United States. It may be argued n
this case, however, that the stations were originally too far fr
shore to have these genera which are more characteristic of shall
littoral conditions.

On the whole, the foraminifera bear out the geological determi
tions based upon the other groups of organisms.

Table of distribution.

	Oligocene.																		Miocene.							Pleistocene.
	Culebra.					Emperador.		Culebra.											Gatun.							
	6009	6010	6012*a*	6012*c*	6012*d*	6015	6016	6019*a*	6019*b*	6019*c*	6019*d*	6019*e*	6019*f*	6020*a*	6020*c*	6024*a*	6025	6026	6029*a*	6029*b*	6029*c*	6030	6033*c*	6035	6036	5850
Textularia abbreviata d'Orbigny		+																								
sagittula Defrance																	+	+								
agglutinans d'Orbigny								+																		
laminata, new species		+																								
subagglutinans, new species																							+			
carinata d'Obigny																									+	
panamensis, new species																							+		+	
Chrysalidina pulchella, new species																							+		+	
Bolivina punctata d'Orbigny																							+	+		
aenariensis (Costa)																							+		+	
robusta H. B. Brady																								+		
Bigenerina nodosaria d'Orbigny																									+	
Gaudryina flintii Cushman		+																								
triangularis Cushman		+																								
Clavulina parisiensis d'Orbigny		+																								
communis d'Orbigny		+																								
Virgulina squamosa d'Orbigny																							+	+	+	
Lagena striata, var. *strumosa* Reuss		+																								
Nodosaria communis d'Orbigny																									+	
insecta Schwager?		+	+																							
raphanistrum (Linnaeus)		+																								
Cristellaria rotulata (Lamarck)		+	+	+																			+	+	+	
italica Defrance																									+	
protuberans, new species		+																								
vaughani, new species		+											+				+							+	+	
Urigerina canariensis d'Orbigny		?																						+		
pygmaea d'Orbigny					+			+																+		
tenuistriata Reuss																									+	
Siphogenerina raphanus, var. *transversus*, new variety		+																								
Globigerina bulloides d'Orbigny	+	+											+							+			+	+	+	
inflata d'Orbigny		+																						+	+	
dubia Egger		+															+						+	+	+	
conglobata H. B. Brady																								+	+	
sacculifera H. B. Brady																									+	
aequilateralis H. B. Brady																							+	+	+	

Orbulina universa d'Orbigny																						+	+	+	
Discorbis obtusa d'Orbigny																									+
Truncatulina americana, new species													+												
pygmea Hantken											+														
ungeriana (d'Orbigny)	+		+																						
wuellerstorfi (Schwager)		+			+								+												
culebrensis, new species					+																				
Pulvinulina oblonga (Williams)																							+		
concentrica Parker and Jones																							+		
menardii (d'Orbigny)																						+	+	+	
Siphonina reticulata (Czjzek)																								+	
Nonionina depressula (Walker and Jacob)																						+	+		
scapha (Fichtel and Moll)																						+			
panamensis, new species		+																							
anomalina Cushman, new species		+																							
Polystomella striato-punctata (Fichtel and Moll)														+					+						+
sagra d'Orbigny																									+
macella (Fichtel and Moll)						+	+																		
crispa (Linnaeus)																				+					
craticulata (Fichtel and Moll)																	+								
Amphistegina lessonii d'Orbigny	+		+		+	+	+			+	+								+	+	+				
Quinqueloculina seminulum (Linnaeus)																								+	+
var.		+						+									+								
contorta d'Orbigny																									+
auberiana d'Orbigny																									+
undosa Karrer							+										+								
bicornis (Walker and Jacob)																									+
panamensis, new species																								+	
Sigmoilina tenuis (Czjzek)																						+	+	+	
asperula (Karrer)																							+	+	
Triloculina trigonula (Lamarck)																									+
tricarinata d'Orbigny																	+								
bulbosa, new species																			+			+			
projecta, new species																							+		
Biloculina bulloides d'Orbigny																								+	
Spiroloculina excavata d'Orbigny																									
Orbiculina adunca (Fichtel and Moll)																									+
Orbitolites americana, new species									+					+	+		+								

DESCRIPTIONS OF SPECIES.

Family TEXTULARIIDAE.

Genus TEXTULARIA Defrance, 1824.

TEXTULARIA ABBREVIATA d'Orbigny.

Plate 19, fig. 1.

Textularia abbreviata d'Orbigny, Foram. Foss. Bass. Tert. Vienne, 1846, p. 249, pl. 15, figs. 9–12 (7–12).

Description.—Test broad and short, somewhat compressed, chambers comparatively few in number, broad near the center and tapering to the periphery, sutures in these specimens indistinct, aperture an arched slit extending nearly across the test, wall comparatively smooth.

Length 0.65 mm., breadth about 1 mm. Cat. No. 324608, U.S.N.M.

Specimens from U.S.G.S. No. 6010, from the Culebra formation, dark clay north of Pedro Miguel Locks. Apparently the material is rather metamorphosed and more or less glauconitic so that little of the original test is preserved. This is a rather common Tertiary species.

TEXTULARIA SAGITTULA Defrance.

Plate 19, fig. 2.

Textularia sagittula Defrance, Dict. Sci. Nat., vol. 32, 1824, p. 177; vol. 53, 1828, p. 344; Atlas, Conch., pl. 13, fig. 5.

Description.—Test elongate, tapering, much compressed especially at sides, chambers numerous, sutures indistinct, aperture a curved slit occupying about one-half the width of the base of the chamber.

Length about 1.5 mm., breadth 1 mm. Cat. No. 324609, U.S.N.M.

A few poorly preserved specimens from U.S.G.S. No. 6025, from the Culebra formation, foraminiferal marl and coarse sandstone about 200 yards south of southern end of switch at Bohio Ridge station, relocated line, Panama Railroad.

Although this material is more or less glauconitic and poorly preserved the three specimens, one of which is here figured, are referred with a reasonable degree of certainty to this species.

A single fragmentary specimen from U.S.G.S. No. 6026, from the Culebra formation, coarse, sandy foraminiferal marl about half way between Monte Lirio and Bohio Ridge, relocated line, Panama Railroad, seems also to be this species.

TEXTULARIA AGGLUTINANS d'Orbigny.

Plate 19, fig. 3.

Textularia agglutinans d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères," p. 136, pl. 1, figs. 17, 18, 32–34.

Description.—Test elongate, tapering, but slightly compressed laterally, chambers high, sutures deep, outline sinuous, end view broadly elliptical, wall composed of rather coarse agglutinated material, aperture a narrow slit a little more than half the width of the base of the chamber.

Length 1.23 mm., breadth 0.65 mm. Cat. No. 324610, U.S.N.M.

A single specimen here figured seems referable to this species. It is from U.S.G.S. No. 6019–*f*, from the uppermost bed of the Culebra formation, the lower limestone of the Las Cascadas section, opposite Las Cascadas, Gaillard Cut. Although not so rounded in end view as this species usually is in recent specimens, the general characters, wall structure, high rotund chambers and lobulated outline seem to place it here.

TEXTULARIA LAMINATA, new species.

Plate 19, fig. 4.

Description.—Test elongate, cuneate, tapering from the widest part near the apertural end, gradually and evenly to the initial end which is subacute, median line raised thence tapering rapidly toward the periphery which is thin and extends out into a lamella-like border, chambers numerous, wide and low, sutural lines raised, somewhat curved backward; border irregular, wall finely arenaceous, aperture indistinct.

Length 2 mm., breadth 1.2 mm.

Specimen figured from U.S.G.S. No. 6010, from lower part of the Culebra formation, dark clay north of Pedro Miguel Locks. Specimen rather better preserved than most from this station. The end view of this specimen is mainly rhomboidal with the bordering carina extending outward in a thin carina. It is in some ways suggestive of *Textularia carinata* but differs in many respects from that species which is also figured on plate 19, fig. 6.

Type-specimen.—Cat. No. 324611, U.S.N.M.

TEXTULARIA SUBAGGLUTINANS, new species.

Plate 19, fig. 5.

Description.—Test subrhomboidal in front view tapering from the middle toward either end, in end view oblong, sides truncated; chambers comparatively few, somewhat inflated, sutures conspicuously

pressed, wall composed of rather coarse arenaceous material, aperture extending into the base of the chamber in a narrow rounded opening deeper than wide.

Length 1.3 mm., breadth 0.85 mm.

This species was fairly common from U.S.G.S. No. 6033*c*, the Gatun formation, in marl from second bed from bottom, just below lower clay, Gatun section, relocated line Panama Railroad.

This species may be distinguished from *Textularia agglutinans* by the truncated sides, the oblong end view and especially by the deep, narrow aperture.

Type specimen.—Cat. No. 324612, U.S.N.M.

TEXTULARIA CARINATA d'Orbigny.

Plate 19, fig. 6.

Textularia carinata d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 263, No. 23; Foram Foss. Bass. Tert. Vienne, 1846, p. 247, pl. 14, figs. 32–34.

Description.—Test much compressed, rather abruptly tapering toward the initial end, sutures strongly limbate, in well-preserved specimens extending out from the periphery in angular spine-like projections, aperture narrow, elongate.

Length 1 mm., breadth 0.65 mm. Cat. No. 324613, U.S.N.M.

The only material of this species is from U.S.G.S. No. 6036, from the Gatun formation, a dark-colored, fine-grained, sandy clay marl from Monkey Hill, Mount Hope Station. It is very evidently this species and is well preserved.

TEXTULARIA PANAMENSIS, new species.

Plate 20, fig. 1.

Description.—Test rhomboid in front view, very much compressed, in end view long and narrow, the faces nearly parallel, sides rounded; composed of comparatively few chambers but variable; long and low, sutures somewhat depressed, wall rather coarsely arenaceous; aperture indistinct.

Length 0.85 mm., breadth 0.65 mm.

The figured specimen is from U.S.G.S. No. 6036, from the Gatun formation, a dark-colored, fine-grained sandy clay marl from Monkey Hill, Mount Hope Station. Specimens were common from U.S.G.S. No. 6033*c*, in marl from second bed from bottom, just below lower clay, Gatun section, relocated Panama Railroad.

This is a rather striking species, with its very flat, broad front view and very compressed character of the test.

Type-specimen.—Cat. No. 324614, U.S.N.M.

Genus CHRYSALIDINA d'Orbigny, 1846.

CHRYSALIDINA PULCHELLA, new species.

Plate 20, fig. 2.

Description.—Test elongate, gently tapering, broadest at the apica end; in end view triangular; early chambers triserial, later ones uni serial; chambers in uniserial portion triangular, the sutures distinct gently curved backward at the angles, outline more or less irregular apertural face gently convex, with indications of numerous circula apertural openings, wall smooth.

Length 0.5 mm., breadth 0.2 mm.

This species occurred at U.S.G.S. No. 6036, the Gatun formatio in dark-colored, fine-grained, sandy clay marl, from Monkey Hil Mount Hope Station.

The species differs from the only known recent species, *Chryso lidina dimorpha*, in the more tapering and elongate test, the greate irregularity of the contour and test in general and its generally les trim and neat appearance. The specimen figured is well preserve in its general characters, except those of the apertural face, whic are somewhat obscured.

Type-specimen.—Cat. No. 324615, U.S.N.M.

Genus BOLIVINA d'Orbigny, 1826.

BOLIVINA cf. B. PUNCTATA d'Orbigny.

Plate 21, fig. 3.

Bolivina punctata d'Orbigny, Voyage Amér. Mérid., vol. 5, pt. 5, "Foram nifères," 1839, p. 63, pl. 8, figs. 10–12.—H. B. Brady, Rep. Voy. *Ch lenger*, Zoology, vol. 9, 1884, p. 417, pl. 52, figs. 18, 19.—Flint, An Rep. U. S. Nat. Mus., 1897 (1899), p. 292, pl. 38, fig. 1.

Description.—Test much elongate, sides nearly parallel, abrupt tapering at the initial end, chambers numerous, usually higher th broad, inflated, sutures distinct but slightly depressed; wall fine punctate, occasionally becoming slightly striate.

Length 0.60 mm., breadth 0.15 mm. Cat. No. 324616*a*, *b*, U.S.N.M.

Specimens which seem referable to this species were obtained U.S.G.S. No. 6033*c*, Gatun formation, marl from second bed fro bottom, just below lower clay, Gatun section, relocated line Panam Railroad and 6035, Gatun formation, from gray green, fine grained sandy shell marl, vicinity of Mindi Hill. There is a tendency f the specimens to take on a semi-striate appearance, an extreme for both in shape and striation shown in plate 21, figure 3.

BOLIVINA AENARIENSIS (Costa).

Plate 21, fig. 2.

Brizalina aenariensis Costa, Atti Acad. Pontaniana, vol. 7, 1856, p. 297, 15, fig. 1, A. B.

Bolivina aenariensis H. B. Brady, Proc. Roy. Soc. Edinburgh, vol. 11, 18 p. 711; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 423, pl. 53, f 10, 11.

Description.—Test much compressed, composed of numerous chambers about twice as broad as high, sutures distinct, slightly curved backward, chambers slightly inflated, especially in the center, test bordered by a narrow but distinct carina; surface smooth except for several longitudinal raised costae radiating from the initial end which carries also a short spine.

Length 0.65 mm., breadth 0.35 mm. Cat. No. 324617*a*, *b*, U.S.N.M.

A few specimens were obtained from U.S.G.S. No. 6033*c*, Gatun formation, in marl from second bed from bottom, just below lower clay, Gatun section, relocated line, Panama Railroad.

While these specimens are not absolutely typical they undoubtedly belong to this species.

Very typical specimens occur at U.S.G.S. No. 6036, Gatun formation, in dark colored, fine grained, sandy clay marl, from Monkey Hill, Mount Hope Station.

BOLIVINA ROBUSTA H. B. Brady.

Plate 21, fig. 4.

Bolivina robusta H. B. Brady, Quart. Journ. Micr. Sci., vol. 21, 1881, p. 57; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 421, pl. 53, figs. 7–9.

Description.—Test compressed, gradually tapering toward the apical end; chambers comparatively few; about twice as broad as high; sutures limbate, gently curved backward, often slightly lobulated or occasionally showing traces of reticulation on the surface, wall otherwise smooth but punctate, not spinose at the apical end.

Length 0.45 mm., breadth 0.25 mm. Cat. No. 324618, U.S.N.M.

These specimens, an extreme form of which is figured, are many of them very close to typical *B. robusta* which is at best either a variable species or one including more than one form. The sutures are usually limbate, as shown in some of Brady's figures, but no apical spine is apparently in any of the specimens in this material. They were from U.S.G.S. No. 6035, Gatun formation, from gray green, fine grained, sandy shell marl, vicinity of Mindi Hill.

BOLIVINA, species?

Plate 21, fig. 1.

This specimen is rather ill-defined and cannot be definitely determined from the single example, the sutures are limbate as in *Bolivina robusta* Brady, but have apparently no secondary extensions as in that species. The whole specimen seems to be replaced. The specimen is from U.S.G.S. 6010, lower part of the Culebra formation, from dark clay north of Pedro Miguel Locks. Cat. No. 324619, U.S.N.M.

Genus BIGENERINA d'Orbigny, 1826.

BIGENERINA NODOSARIA d'Orbigny.

Plate 21, fig. 5.

Bigenerina nodosaria d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 261, pl. 11, figs. 9–11.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 1884, p. 369, pl. 44, figs. 14–18.

Description.—Test elongate, subcylindrical, early portion consisting of a few chambers arranged as in *Textularia*, later ones uniserial, early portion tapering abruptly toward the apical end, wall coarsely arenaceous, sutures rather indistinct, aperture circular and central.

Length 2 mm., breadth 0.8 mm. Cat. No. 324620, U.S.N.M.

Several specimens in excellent condition were obtained from U.S.G.S. No. 6036, Gatun formation, in dark-colored, fine-grained sandy clay marl from Monkey Hill, Mount Hope Station.

These specimens, as in the one figured, have but a slight indication of the biserial chambers from the exterior, but otherwise seem to be typical. At first glance they might be taken for a species of *Clavulina*.

Genus GAUDRYINA d'Orbigny, 1839.

GAUDRYINA FLINTII Cushman.

Plate 20, fig. 4.

Gaudryina subrotundata Flint (not *G. subrotundata* Schwager, 1866), Ann. Rep. U. S. Nat. Mus., 1897 (1899), p. 287, pl. 33, fig. 1.

Gaudryina flintii Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 8, fig. 102*a–c*.

Description.—Test subconical, early portion rounded conical, triserial, later portion subcylindrical, biserial chambers of later portion nearly semicircular in transverse section, sutures distinct; wall arenaceous; aperture subcircular, at the base of the inner margin of the chamber.

Length 1.20 mm., breadth 0.72 mm. Cat. No. 324621.

A single specimen which seems to be close to recent specimens of this species was obtained from U.S.G.S. No. 6010, lower part of the Culebra formation, in dark clay, north of Pedro Miguel Locks. The specimen is somewhat glauconitic and certain of the details are more or less obscured.

GAUDRYINA TRIANGULARIS Cushman.

Plate 20, fig. 3.

Gaudryina triangularis Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 65, figs. 104*a–c*.

Description.—Test somewhat longer than broad, early portion triangular, the faces somewhat concave, triserial; later portion biserial,

rounded in transverse section; wall coarsely arenaceous, chambers comparatively few, sutures indistinct, aperture a narrow slit at the base of the inner margin of the last formed chamber.

Length 1.7 mm., breadth 1.0 mm. Cat. No. 324622, U.S.N.M.

A single specimen which seems to belong to this species was found in material from U.S.G.S. No. 6010, lower part of the Culebra formation, in dark clay, north of Pedro Miguel Locks. The specimen, like many others from this station, is glauconitic and not well preserved in all its details.

Genus CLAVULINA d'Orbigny, 1826.

CLAVULINA PARISIENSIS d'Orbigny.

Plate 20, fig. 5.

Clavulina parisiensis d'Orbigny, Ann. Sci. Nat., vol. 7, 1826. p. 268.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 395, pl. 48, figs. 14–18.

Description.—Test elongate, subcylindrical, early portion conical, later portion gradually increasing in diameter toward the apertural end, chambers comparatively few, those of the uniserial portion circular in cross section, wall coarsely arenaceous, somewhat rough; aperture circular, terminal.

Length nearly 2 mm., diameter 0.7 mm. Cat. No. 324623, U.S.N.M.

A single specimen representing this species was obtained in material from U.S.G.S. No. 6010, lower part of the Culebra formation, in dark clay north of Pedro Miguel Locks. Both this and the following are common Tertiary species.

CLAVULINA COMMUNIS d'Orbigny.

Plate 20, fig. 6.

Clavulina communis d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 268; Foram. Foss. Bass. Tert. Vienne, 1846, p. 196, pl. 12, figs. 1, 2.

Description.—Test very elongate, subcylindrical, circular in transverse section, early portion triserial, later portion uniserial, of rather uniform diameter, sutures more or less indistinct, wall smooth; aperture terminal.

Length 2 mm., breadth 0.45 mm. Cat. No. 324624, U.S.N.M.

A single specimen of this species occurred with the preceding, U.S.G.S. No. 6010, in the lower part of the Culebra formation. It is fragmentary but probably represents this species.

Genus VIRGULINA d'Orbigny, 1826.

VIRGULINA SQUAMOSA d'Orbigny.

Plate 21, fig. 6.

Virgulina squamosa d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 267.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 91, fig. 145*a*, *b*.

Description.—Test elongate, tapering gradually to the apical end and again toward the apertural end, chambers comparatively few inflated, sutures distinct, wall smooth, aperture a comma-like slit at the base of the last formed chamber.

Length 0.7 mm., breadth 0.25 mm. Cat. No. 324625*a*, *b*, *c*, U.S.N.M.

Specimens of this species occurred in the Gatun formation at the following three stations, U.S.G.S. No. 6033*c*, marl from second bed from bottom, just below lower clay, Gatun Section, relocated line Panama Railroad; U.S.G.S. No. 6035, in gray-green, fine-grained sandy shell marl vicinity of Mindi Hill, and U.S.G.S. No. 6036, in dark-colored fine-grained, sandy clay marl, at Monkey Hill, Mount Hope Station.

At none of these stations were more than a few specimens found but all seem referable to this species.

Family LAGENIDAE.

Genus LAGENA Walker and Boys, 1784.

LAGENA STRIATA (d'Orbigny), var. STRUMOSA Reuss.

Plate 21, fig. 7.

Lagena strumosa Reuss. Zeitschr, geol. Ges., 1858, p. 434; Sitz, Akad Wiss. Wien, vol. 46, pt. 1, 1862 (1863), p. 328, pl. 4, fig. 49.

Lagena striata (d'Orbigny), var. *strumosa* Cushman, Bull. 71, U. S. Nat Mus., pt. 3, 1913, p. 20, pl. 7, figs. 7–10.

Description.—Test clavate or subglobular, the body portion ornamented with numerous longitudinal raised costae, apical end with single stout spine; neck short and stout, typically with a phialine li and transverse costae.

Diameter 0.5 mm. Cat. No. 324626, U.S.N.M.

A single specimen of this variety was obtained in material fro U.S.G.S. No. 6010, from the lower part of the Gatun formation, dar clay, north of Pedro Miguel Locks. This is the only representativ of the genus in the whole series of samples examined. The spec men lacks the neck except the base and the tip of the apical spine.

Genus NODOSARIA Lamarck, 1812.

NODOSARIA COMMUNIS d'Orbigny.

Plate 21, fig. 8.

Nodosaria (*Dentalina*) *communis* D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 254, No. 35.

Nodosaria communis REUSS, Verst. Böhm. Kreid., pt. 1, 1845, p. 28, pl. 12, fig. 21.—H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 504, pl. 62, figs. 19–22.

Description.—Test elongated, slender, gradually tapering, slightly urved, chambers slightly inflated in the middle, sutures distinct, lightly depressed, somewhat oblique; wall smooth.

Length 2 mm.? Cat. No. 324627.

A single fragment showing four chambers was obtained in material rom U.S.G.S. No. 6036, Gatun formation, from dark-colored fine-rained, sandy clay marl at Monkey Hill, Mount Hope Station. The ragment with its general characters, its smooth surface, slightly nflated chambers and oblique sutures seem to clearly indicate this pecies.

NODOSARIA INSECTA Schwager?

Plate 21, fig. 9.

Nodosaria insecta SCHWAGER, *Novara* Exped. Geol. Thiel., pt. 2, 1866, p. 224, pl. 5, figs. 52, 53.

Description.—Test elongate, gradually tapering from the nearly cute slender base to a broad apical end, which is the greatest in iameter of any of the chambers of the test; chambers numerous, nflated, nearly spherical, sutures much depressed; wall smooth, pertures with a slight neck and circular opening.

Length 2.3 mm. Cat. No. 324628*a*, *b*, U.S.N.M.

Specimens were found in the lower part of Culebra formation both t U.S.G.S. No. 6010, in dark clay, north of Pedro Miguel Locks, nd 6012*a*, from lower dark clay beneath lower conglomerate, one-ourth mile south of Empire Bridge.

The specimens are very close to the species described by Schwager rom the Tertiary of Kar Nicobar. The two forms, megalospheric nd microspheric, occur in the Panamanian material, the latter being uch more slender at the initial end than in the megalospheric.

NODOSARIA RAPHANISTRUM (Linnaeus).

Plate 21, fig. 10.

Nautilus raphanistrum LINNAEUS, Syst. Nat., ed. 10, 1758, p. 710.

Nodosaria raphanistrum REUSS, in Geinitz, Grundr. Verstein, 1845–46, p. 653, pl. 24, fig. 6.—JONES, PARKER, and H. B. BRADY, Monogr. Pal. Soc., vol. 19, 1866, p. 50, pl. 1, figs. 6–8.

Description.—Test elongate, subcylindrical, slightly tapering, chambers numerous, distinct, apertural end with a short tapering neck; wall ornamented with longitudinal costae continued clear to the aperture, about 12–15 in number.

Length 4 mm. Cat. No. 324629, U.S.N.M.

A single specimen of this species figured here was obtained from U.S.G.S. No. 6010, lower part of the Culebra formation, in dark clay, north of Pedro Miguel Locks. The specimen is not complete at the initial end but the last six chambers including the aperture are very well preserved.

NODOSARIA, species?

Plate 21, fig. 11.

A fragment consisting of one complete chamber and the adjacent parts of two others was found in the same material, U.S.G.S. No. 6010, as the above but nearly twice the diameter. The costae are also more numerous. Without further material it is unsafe to try to determine the fragment, but the occurrence of another species at this station should be at least recorded. Cat. No. 624630, U.S.N.M.

Genus CRISTELLARIA Lamarck, 1812.

CRISTELLARIA ROTULATA (Lamarck).

Plate 22, fig. 1.

"Cornu Hammonis seu Nautili" PLANCUS, Conch. Min., 1739, p. 13, pl. 1 fig. III.

Lenticulites rotulata LAMARCK, Ann. Mus., vol. 5, 1804, p. 188, No. 3; vol. 8 1806, pl. 62, fig. 11.

Cristellaria rotulata D'ORBIGNY, Mem. Soc. Géol. France, ser. 1, vol. 4, 184(p. 26, pl. 2, figs. 16–18.—H. B. BRADY, Rep. Voy. *Challenger*, Zoology vol. 9, 1884, p. 547, pl. 69, figs. 13*a*, *b*.

Description.—Test comparatively large, biconvex, close coile throughout, chambers variable in number in the coil, sutures distinc periphery not lobulated, usually not keeled; previous apertures o the test usually visible as is often the preceding coil at least in part wall smooth.

Diameter up to 2 mm. Cat. Nos. 324631*a*, *b*, *c*, *d*, *e*, U.S.N.M.

This seems to be the commonest species in the Panamanian materia It differs slightly in form in the various stations but all may b grouped under this species. It occurred in two groups of statior as noted in the chart of distribution. They are as follows: Lowe part of the Culebra formation at U.S.G.S. No. 6010, in dark cla north of Pedro Miguel Locks; No. 6012*a*, in lower dark clay beneat lower conglomerate, one-fourth mile south of Empire Bridg Gatun formation at U.S.G.S. No. 6033*c*, in marl from second be

rom bottom just below lower clay, Gatun section, relocated line anama Railroad; No. 6035, in gray green, fine-grained, sandy shell arl, vicinity of Mindi Hill; and No. 6036 in dark-colored, fine-rained, sandy clay marl of Monkey Hill, Mount Hope Station.

CRISTELLARIA ITALICA (Defrance).

Saracenaria italica Defrance, Dict. Sci. Nat., vol. 32, 1824, p. 177; vol. 47, 1827, p. 344; Atlas Conch., pl. 13, fig. 6.

Cristellaria (*Saracenaria*) *italica* d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 293, No. 26; Modèles, Nos. 19 and 85.

Cristellaria italica Parker, Jones, and H. B. Brady, Ann. Mag. Nat. Hist., ser. 3, vol. 16, 1865, pp. 21, 32, pl. 1, figs. 41, 42.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 544, pl. 68, figs. 17, 18, 20–23.

Description.—Test with the early portion close coiled, later portion more or less uncoiled, chambers numerous, those of the last-formed portion being triangular in cross section, periphery keeled, and the apertural face broad and flattened, the sides angled and extending on either side to the keel in flat faces, sutures but slightly depressed, wall smooth; apertures peripheral, radiate, usually with no neck.

Diameter 0.75 mm. Cat. No. 324632, U.S.N.M.

Two specimens are evidently of this species in a young stage, the uncoiling not yet having proceeded to a great degree. They are from U.S.G.S. No. 6036, Gatun formation, in dark-colored, fine-grained, sandy clay marl from Monkey Hill, Mount Hope Station.

CRISTELLARIA PROTUBERANS, new species.

Plate 22, fig. 2.

Description.—Test compressed, close coiled, biconvex, seven chambers in each coil, each much inflated in its central portion, space between much compressed, flattened, periphery sharply and broadly keeled; aperture peripheral, radiate.

Diameter 0.80–1.20 mm.

Three specimens of this species occurred at U.S.G.S. No. 6010, lower part of Culebra formation, in dark clay north of Pedro Miguel locks. It is in some respects similar to species found in the Western Pacific, especially in comparatively deep water off the Philippines.

Type-specimen.—Cat. No. 324633, U.S.N.M.

CRISTELLARIA VAUGHANI, new species.

Plate 22, fig. 3.

Description.—Test much compressed, with a slight tendency to uncoiling in the last-formed chambers, periphery slightly keeled, not tuberculated, rounded, about nine chambers in the last-formed whorl.

sutures slightly curved backward, extending in to the umbilicus so that only the last-formed coil is visible from the exterior, surface smooth except for lines of beads along the sutures extending from the umbilicus to the periphery; apertural face truncated or even slightly concave, aperture radiate, peripheral, with a short cylindrical neck.

Diameter 0.75 mm.

The type-sections of this species are from U.S.G.S. No. 6037, Gatun formation, in gray green, fine-grained, sandy shell marl from the vicinity of Mindi Hill. It also occurred at 6036, Gatun formation, in dark-colored, fine-grained, sandy clay marl from Monkey Hill, Mount Hope Station; No. 6019*f*, upper part of Culebra formation, fourth limy bed from bottom, section opposite Las Cascadas Gaillard Cut; and No. 6010, lower part of Culebra formation, in dark clay, north of Pedro Miguel Locks.

This species is somewhat suggestive of some forms of *C. wetherelli* but has no longitudinal ribbing. It is perhaps nearest to *C. gemmata* described by Brady from the Philippines and South Sea Islands, but lacks the typical papillate surface common in that species.

The species is named for Dr. T. Wayland Vaughan, whose collections in the Canal Zone have added much to the available foraminifera from this region.

Type-specimens.—Cat. No. 324634, U.S.N.M.

Genus UVIGERINA d'Orbigny, 1826.

UVIGERINA CANARIENSIS d'Orbigny.

Plate 22, fig. 5.

"Testae pineiforme minusculae" Soldani, Testaceographia, vol. 2, 17[illegible], p. 18, pl. 4, figs. E, F, G, H.

Uvigerina nodosa, var. *B* d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 269, No. [illegible].

Uvigerina canariensis d'Orbigny, Foram. Canaries, 1839, p. 138, pl. 1, figs. 25–27.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. [illegible], pl. 74, figs. 1–3.

Description.—Test elongate, chambers numerous, spirally arranged, triserial, inflated, separated by distinct sutures; wall smooth except for the early chambers which may show traces of spines or longitudinal striae; apertural end usually with a tubular neck and often a phialine lip.

Length 0.75 mm., diameter 0.35 mm. Cat. No. 324635, U.S.N.M.

The only typical material of this species is from U.S.G.S. No. 6035, Gatun formation, in gray-green, fine-grained sandy shell marl from the vicinity of Mindi Hill.

UVIGERINA CANARIENSIS d'Orbigny, variety.

Plate 22, fig. 6.

A larger and much stouter, entirely smooth variety as shown in the above figure was found in material from U.S.G.S. No. 6010, lower part of Culebra formation, in dark clay, north of Pedro Miguel Locks. Cat. No. 324636, U.S.N.M.

UVIGERINA PYGMAEA d'Orbigny.

Plate 22, fig. 4.

"Polymorpha Pineiformia" Soldani, Testaceographia, vol. 1, pt. 2, 1791, pl. 130, figs. *ss*, *tt*.

Uvigerina pigmea d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 269, pl. 12, figs. 8, 9; Modèles, 1826, No. 67.

Uvigerina pygmaea d'Orbigny, Foram. Foss. Bass. Tert. Vienne, 1846, p. 190, pl. 11, figs. 25, 26.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 575, pl. 74, figs. 11–14.

Description.—Test subcylindrical, triserially spiral, chambers numerous, inflated, sutures deep; wall ornamented by numerous longitudinal costae, those of each chamber usually independent of those of adjacent chambers; aperture with a short cylindrical neck and phialine lip.

Length 0.75 mm., breadth 0.32 mm. Cat. No. 324637*a*, *b*, *c*, U.S.N.M.

Specimens referable to this species occurred in the Culebra formation at U.S.G.S. No. 6012*a*, in lower dark clay beneath lower conglomerate, one-fourth mile south of Empire Bridge, Gaillard Cut, and No. 6012*d* in clay and sandstone just below conglomerate at base of green clay one-half to three-fourths of a mile north of Contractors Hill, Gaillard Cut.

Specimens of a slightly different character were abundant at No. 6035, Gatun formation, in gray-green, fine-grained sandy shell marl, vicinity of Mindi Hill.

UVIGERINA TENUISTRIATA Reuss.

Plate 22, fig. 7.

Uvigerina striata Reuss, Sitz. Kais. Akad. Wiss. Wien, vol. 52, 1870, p. 485.—von Schlicht, Foram. Pietzpuhl, 1870, pl. 22, figs. 34–36.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 574, pl. 74, figs. 4–7.

Description.—Test subcylindrical, chambers spirally arranged, triserial at least in the early portion, later portion sometimes biserial and more slender; chambers inflated, sutures deep, walls ornamented by numerous longitudinal costae, except the last chambers, which tend to become smooth or nearly so; aperture with a short tubular neck and often a phialine lip.

Length 0.85 mm., breadth 0.30 mm. Cat. No. 324638, U.S.N.M.

Specimens referred to this species were very common in mater from U.S.G.S. No. 6036, Gatun formation, in dark-colored, fi grained sandy clay marl, from Monkey Hill, Mount Hope Stati Many of the specimens become almost uniserial in the last-form portion.

Genus SIPHOGENERINA Schlumberger, 1883.

SIPHOGENERINA RAPHANUS (Parker and Jones) var. TRANSVERSUS, new variety

Plate 22, fig. 8.

Description.—Test subcylindrical, composed of comparatively f chambers, the earlier ones spirally arranged, later and greater p tion of the test uniserial, sutures very prominently indented, e tween the longitudinal costae, aperture with a short cylindrical ne

Length, 1.25 mm.; diameter, 0.54 mm. Cat. No. 324646, U.S.N

This variety differs from the typical form in the much grea prominence of the transverse depressions marking the sutures, oc sionally as in the figure suggesting the depressions of *S. dimorpa* The specimens were frequent in material from U.S.G.S. No. 60 lower part of the Culebra formation, in dark clay, north of Pe Miguel Locks.

Family GLOBIGERINIDAE.

Genus GLOBIGERINA d'Orbigny, 1826.

GLOBIGERINA BULLOIDES d'Orbigny.

Globigerina bulloides d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 277, N Modèles, No. 17, and No. 76; in Barker, Webb, and Berthelot, Hist Nat. Isles Canaries, 1839, pt. 2, Foraminifères, p. 132, pl. 2, figs. 3 28.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 93 pl. 77; pl. 79, figs. 3–7.

Description.—Test subglobose, spiral, visible portion composed of but few chambers from below, usually three to five, all visible from the dorsal side, sutures deep, chambers inflated, umbilicate below; surface reticulate; aperture single, from each chamber, of good size opening into the central umbilical cavity on the ventral side.

Diameter, 0.60 mm. Cat. Nos. 324639–45.

Specimens referable to this widely distributed species were obtained from the following stations: In the Culebra formation, U.S.G.S. No. 6009, from black clays and sandy beds at lower end of Pedro Miguel Locks; 6010 in dark clay, north of Pedro Miguel Locks; 6019*f*, in fourth limy bed from bottom, Las Cascadas section, Gaillard Cut. In the Gatun formation, U.S.G.S. No. 6019*b*,

in argillaceous and sandy indurated marl, one-fourth to one-half mile north of Camp Cotton on relocated line, Panama Railroad: 6033*c* in marl from second bed from bottom, just below lower clay, Gatun Section relocated line, Panama Railroad; 6035, in gray green, fine grained, sandy shell marl, near Mindi Hill; and 6036, in dark colored, fine grained, sandy clay marl, Monkey Hill, Mount Hope Station.

The specimens from the last three stations are very well preserved and in fact might almost be recent material, while those of the other stations were fragmentary, often glauconitic. *G. bulloides*, var. *triloba* Reuss was occasional in the last three stations where the genus was really very common.

GLOBIGERINA INFLATA d'Orbigny.

Globigerina inflata d'Orbigny, in Barker, Webb, and Berthelot, Hist. Nat. Isles Canaries, vol. 2, pt. 2, 1839, Foraminifères, p. 134, pl. 2, figs. 7–9.—H. B. Brady, Rep. Voy, *Challenger*, Zoology, vol. 9, 1884, p. 601, pl. 79, figs. 8–10.

Description.—Test composed of numerous inflated chambers usually arranged in a spiral test with about three volutions, the last-formed one with four chambers, dorsal side of test nearly flat, ventral side extended, especially in the last-formed whorl; ventrally umbilicate; surface finely reticulate; aperture large, opening toward the umbilicus.

Diameter, 0.75 mm. Cat. Nos. 324647, 8, 9, U.S.N.M.

Specimens occurred at U.S.G.S. No. 6010, lower part of the Culebra formation, in dark clay north of Pedro Miguel Locks; and in the Gatun formation at the last two of the stations already referred to, namely, 6035 and 6036.

GLOBIGERINA DUBIA Egger.

Globigerina dubia Egger, Neues Jahrb. für Min., 1857, p. 281, pl. 9, figs. 7–9.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 595, pl. 79, figs. 17*a–c*.

Description.—Test composed of numerous inflated chambers arranged in a nautiloid spiral all visible from above, the last coil only, consisting of 5 to 6 chambers, visible from below, ventral side with a central umbilicus, surface reticulate; apertures opening into the central umbilical cavity.

Diameter 0.75 mm. Cat. Nos. 324650–54.

At the following stations specimens referable to this species were found: Culebra formation, U.S.G.S. No. 6010, in dark clay, north of Pedro Miguel Locks; 6025, in dark, hard, sandy clay about 200

yards south of southern end of switch at Bohio Ridge Station, r located line, Panama Railroad. Gatun formation, U.S.G.S. N 6033*c*, in marl from second bed from bottom, just below lower cla Gatun Section, relocated line, Panama Railroad; 6035, in gray gree fine grained, sandy shell marl near Mindi Hill and 6036 in da colored, fine grained, sandy clay marl, Monkey Hill, Mount Ho Station.

As in the case of the preceding species the specimens from t last three stations were very finely preserved while those of t others were glauconitic.

GLOBIGERINA CONGLOBATA H. B. Brady.

Globigerina conglobata H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 18 p. 72; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 603, pl. 80, fi 1–5; pl. 82, fig. 5.

Description.—Test subglobular, early chambers arranged in a co pact spiral, the last three chambers in the complete adult test for ing nearly the whole of the visible portion of the test, wall coarse reticulate; main aperture at the inner margin of the chamber wi several rounded secondary apertures along the margins of t chamber where it is attached to adjacent ones.

Diameter up to 1 mm. Cat. Nos. 324655–6.

Specimens of *G. conglobata* were found in small numbers in t Gatun formation at stations 6035 and 6036. They were typical b perhaps hardly as well developed as in some Recent material. occurrence here is rather interesting as it is almost unknown in t fossil condition.

GLOBIGERINA SACCULIFERA H. B. Brady.

Globigerina helicina Carpenter (not *G. helicina* d'Orbigny). Intr. Fora 1862, pl. 12, fig. 11.

Globigerina sacculifera H. B. Brady, Geol. Mag., Dec. 2, vol. 4, 1877 p. 535; Quart. Journ. Micr. Sci., vol. 19, 1879, p. 73; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 604, pl. 80, figs. 11–17; pl. 82, fig. 4.

Description.—Test composed of numerous chambers, in its ea y stages very similar to *G. bulloides* but later developing a more oblo g form, the chambers extended, somewhat compressed and with a cessory apertural openings, the final chamber often flattened a d irregularly formed toward the outer end; wall strongly reticula d in all but the final chamber which is much smoother than the othe s; aperture large, arched, with other accessory openings in the chamb rs of adult specimens.

Diameter up to 1 mm. Cat. Nos. 324657–8, U.S.N.M.

Specimens were not uncommon in material from the Gatun formation at stations 6035 and 6036. As in the case of *G. conglobata* the specimens were hardly as well developed as they are in recent specimens, but nevertheless had the characteristic marks of the species. As in *G. conglobata* the records of this species are almost entirely limited to Recent material, its occurrence as a fossil being practically unknown.

GLOBIGERINA AEQUILATERALIS H. B. Brady.

Cassidulina globulosa (part) Egger, Neues Jahrb. für Min., 1857, p. 296, pl. 11, fig. 4.

Globigerina aequilateralis H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 71; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 605, pl. 80, figs. 18–21.

Description.—Test composed of numerous inflated chambers, arranged in a planospiral manner, at least the last formed coil, chambers increasing rapidly in size as added, usually 5 to 6 in the last formed volution; sutures depressed, periphery lobulated; surface reticulate; aperture large, at the base of the inner margin of the chamber.

Diameter up to 1 mm. Cat. Nos. 324659–61, U.S.N.M.

In the material from the Gatun formation at three stations, Nos. 6033*c*, 6035, 6036, this species was not uncommon. The only character in which there seems to be a difference from the Recent material is in the early chambers which occasionally show at one side as a flat spiral while the later chambers are bilateral. The species is not a common one as a fossil.

Genus ORBULINA d'Orbigny, 1839.

ORBULINA UNIVERSA d'Orbigny.

Orbulina universa d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, Foraminifères, p. 3, pl. 1, fig. 1.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 608, pl. 78; pl. 81, figs. 8–26; pl. 82, figs. 1–3.

Description.—Test in adult form typically consisting of a single, spherical visible chamber, which may or may not have contained within the early Globigerine stages; wall strongly reticulate, a single large circular aperture and smaller openings at the base of each reticulation.

Diameter up to 1 mm. Cat. Nos. 324662–3, U.S.N.M.

Specimens were not uncommon in the Gatun formation at the three stations, Nos. 6033*c*, 6035, and 6036. Occasional specimens show the double form as figured by Brady. The specimens otherwise are like the common run of Recent material.

Family ROTALIIDAE.

Genus DISCORBIS Lamarck, 1804.

DISCORBIS OBTUSA (d'Orbigny).

Plate 23, figs. 1*a–c*.

Rosalina obtusa D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846. p. 17
pl. 11, figs. 4–6.

Discorbina obtusa H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 188
p. 644, pl. 91, figs. 9*a–c*.

Discorbis obtusa CUSHMAN, Bull. 71. U. S. Nat. Mus., pt. 5, 1915, p. 1
figs. 12*a–c*.

Description.—Test biconvex, dorsal side more so than the ventra
side, peripheral margin rounded; chambers comparatively few, abou
five in the last formed whorl; sutures curved, depressed; wall pe
forate; aperture an elongate narrow slit extending from the un
bilicus nearly to the periphery.

Diameter 0.60 mm. Cat. No. 324664, U.S.N.M.

The only station from which this species was obtained is U.S.G.
No. 5850, from Pleistocene marl near Mount Hope, a quarter mi
from the present sea beach and 6 to 8 feet above high tide.

Genus TRUNCATULINA d'Orbigny, 1826.

TRUNCATULINA AMERICANA, new species.

Plate 23. figs. 2*a–c*.

Description.—Test nearly plano-convex: ventral side strong
convex. periphery keeled, dorsal side nearly flat; chambers numero
up to nine in the last formed coil; sutures curved, prominent, slight
limbate. umbilicate below; surface smooth, aperture nearly p
ripheral.

Diameter 0.65 mm.

Type-specimen.—(Cat. No. 324665, U.S.N.M.) from the upp
part of the Culebra formation, at U.S.G.S. No. 6019*f*, fourth lim
bed from bottom, Las Cascades section, Gaillard Cut.

TRUNCATULINA PYGMEA Hantken.

Plate 23, figs. 3*a–c*.

Truncatulina pygmea HANTKEN, Mitth. Jahrb. ung. geol. Abstalt., vol
1875, p. 78, pl. 10, fig. 8.

Truncatulina pygmaea H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol
1884, p. 666, pl. 95, figs. 9, 10.

Description.—Test nearly equally biconvex, peripheral margin bluntly rounded; chambers numerous, the sutures oblique, distinct, often limbate; aperture a narrow slit extending from near the periphery nearly to the umbilicus.

Diameter 0.65 mm. Cat. No. 324666–7, U.S.N.M.

The only station at which this species occurred is in the upper part of the Culebra formation, U.S.G.S. No. 6019*d*, upper part of second hard, limy, sandstone bed, Las Cascadas section, Gaillard Cut. It is rather larger than the usual run of *T. pygmaea* but is evidently this species.

Specimens from the Gatun formation, U.S.G.S. No. 6036, while having fewer chambers and somewhat larger size are questionably referred here. One specimen is figured on plate 24, figure 2.

TRUNCATULINA UNGERIANA (d'Orbigny).

Plate 24, fig. 1.

Rotalina ungeriana D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 157, pl. 8, figs. 16–18.

Planorbulina ungeriana H. B. BRADY, Trans. Linn. Soc. London, vol. 24, 1864, p. 469, pl. 48, fig. 12.

Truncatulina ungeriana REUSS, Denkschr. Akad. Wiss. Wien, vol. 25, 1865, p. 161.—H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 664, pl. 94, figs. 9*a–d*.

Description.—Test biconvex, dorsal side less convex than the ventral; peripheral margin subacute, slightly carinate, chambers numerous, 10 to 12 in the last formed whorl, sutures distinct, slightly limbate on the dorsal side; aperture a narrow arched opening running ventrally from the peripheral margin.

Diameter 0.50 mm. Cat. Nos. 324668–9, U.S.N.M.

Specimens referable to this species but not entirely typical were obtained in material from lower part of the Culebra formation, as follows: U.S.G.S. No. 6009, from black clays and sandy beds at lower end of Pedro Miguel Locks; and 6012*a*, from lower dark clay beneath lower conglomerate, one-fourth mile south of Empire Bridge, west side Gaillard Cut, below Culebra.

TRUNCATULINA WUELLERSTORFI (Schwager).

Plate 24, fig. 3.

Anomalina wuellerstorfi SCHWAGER, *Novara* Exped., geol. Theil., vol. 2, 1866, p. 258, pl. 7, figs. 105, 107.

Truncatulina wuellerstorfi H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 662, pl. 93, figs. 8, 9.

Description.—Test plano-convex, dorsal side nearly flat, ventral side slightly convex; chambers numerous, elongate, curved; sutures

strongly curved, somewhat limbate, periphery bluntly rounded, slightly lobulated, especially near the apertural end of the last formed coil; wall coarsely punctate; aperture peripheral, a short curved opening.

Diameter of larger specimens slightly more than 1 mm.

Numerous very typical specimens of this species occurred in material from the lower part of the Culebra formation, U.S.G.S. No. 6010, from dark clay, north of Pedro Miguel Locks. Less typical specimens occurred in the upper part of the Culebra formation at U.S.G.S. 6012*d*, from clay and sandstone just below conglomerate at base of green clay, west side of Gaillard Cut, below Culebra; and 6019*f*, from fourth limy bed from bottom, Las Cascadas section, Gaillard Cut.

Cat. Nos. 324670–2, U.S.N.M.

TRUNCATULINA CULEBRENSIS, new species.

Plate 24, figs. 4*a*, *b*.

Description.—Test biconvex, much compressed, peripheral margin rounded; chambers numerous, as many as thirteen in the last formed coil, long and narrow, gently curved, sutures broad, limbate, smooth, the areas between very coarsely punctate; apertural face of chamber somewhat depressed, flattened, the carinate borders extending out beyond at either side; aperture a narrow slit situated at the base of the chamber on the periphery.

Diameter up to 1.5 mm.

The only occurrence of this species was in the upper part of the Culebra formation, U.S.G.S. No. 6012*c*, from top part of limy sandstone below upper conglomerate near foot of stairs, west side Gaillard Cut.

This, a large and striking species, in some of its characters suggesting *T. wuellerstorfi* but, as will be seen by a comparison of the figures of the two, really very different.

Type-specimen.—Cat. No. 324673, U.S.N.M.

Genus PULVINULINA Parker and Jones, 1862.

PULVINULINA SAGRA (d'Orbigny).

Plate 24, figs. 6*a*, *b*.

Rotalina sagra D'ORBIGNY, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 183 Foraminifères, p. 77, pl. 5, figs. 13–15.

Description.—Test ovate, biconvex, the ventral side more convex than the dorsal, peripheral margin subacute, carinate; chambers comparatively few in number increasing rapidly in size in the last formed

nes, the last formed chamber on the ventral side making up a large part of the area of the test, sutures distinct, curved, slightly depressed, more so on the ventral side; wall smooth except for the usual fine punctations; aperture ventral near the umbilicus.

Length 0.60 mm., breadth 0.40 mm. Cat. No. 324674.

The only record for this species from Panama is from the Gatun formation, U.S.G.S. No. 6035, in gray green, fine grained, sandy shell marl, near Mindi Hill. This species, described by d'Orbigny from Cuba, seems to be a common species in the American Miocene.

PULVINULINA CONCENTRICA Parker and Jones.

Plate 25, fig. 1.

Pulvinulina concentrica (Parker and Jones, MS.) H. B. Brady, Trans. Linn. Soc. London, vol. 24, 1864, p. 470, pl. 48, fig. 14.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 686, pl. 105, figs. 1*a–c*.

Description.—Test biconvex, oval; peripheral margin rounded; chambers comparatively few, usually seven in the last formed coil, sutures covered by clear shell material joining with the carinal border and often covering a large portion of the test, both above and below, especially toward the center; wall smooth, finely punctate; aperture a narrow slit on the peripheral portion of the ventral side.

Diameter 1.2 mm. Cat. No. 324675, U.S.N.M.

The only specimen of this species is from the Gatun formation, U.S.G.S. No. 6035, in gray green, fine grained, sandy shell marl near Mindi Hill. The specimen as will be seen from the figure is very typical.

PULVINULINA MENARDII (d'Orbigny).

Plate 25, figs. 2, 3.

Rotalia menardii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 273, No. 26; Modèles, No. 10.

Pulvinulina menardii Owen, Journ. Linn. Soc. London (Zool.), vol. 9, 1867, p. 148, pl. 5, fig. 6.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 690, pl. 103, figs. 1, 2.

Description.—Test plano-convex, ventral side convex, dorsal side nearly flat; compressed, umbilicate; peripheral margin thin, slightly lobulated, carinate; chambers five or six in the last formed coil; sutures distinct, limbate and broad on the dorsal side, curved, on the ventral side more depressed, not limbate, nearly straight; wall smooth, finely punctate; aperture extending peripherally from the umbilicus, usually with an overhanging lip.

Diameter up to 1 mm. Cat. Nos. 324676–8, U.S.N.M.

Specimens apparently belonging to this species so widely distributed in the present oceans were obtained in the Gatun formation at U.S.G.S. No. 6035 in gray green, fine grained, sandy shell marl,

vicinity of Mindi Hill; and 6036 in dark colored, fine grained, sandy clay marl from Monkey Hill, near Mount Hope Station. A figure of one of these is shown in plate 25, figure 3. From 6033*c*, Gatun formation, in marl from second bed from bottom, just below lower clay, Gatun section, relocated line of the Panama Railroad, are even more typical specimens, one of which is here figured on plate 25, figure 2.

Genus SIPHONINA Reuss, 1849.

SIPHONINA RETICULATA (Czjzek).

Plate 24, fig. 5.

Rotalina reticulata Czjzek, Haidinger's Nat. Abh., vol. 2, 1848, p. 145, pl. 13, figs. 7–9.

Siphonina reticulata Brown, Lethaea Geognostica, ed. 3, vol. 3, 1853–56, p. 227, pl. 35 (?), figs. 23*a–c*.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 5, 1915, p. 43, fig. 48; pl. 16, fig. 4; pl. 28, fig. 3.

Truncatulina reticulata H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 669, pl. 96, figs. 5–8.

Description.—Test biconvex, ventral side slightly more so than the dorsal, peripheral margin acute, carinate; chambers numerous, rather indistinct, sutures slightly depressed, curved; wall rather coarsely perforate; aperture peripheral with a short, broad neck and somewhat flaring phialine lip.

Diameter 0.65 mm. Cat. No. 324679, U.S.N.M.

The only station at which this species occurred is in the Gatun formation, U.S.G.S. No. 6036, in dark colored, fine grained, sandy clay marl of Monkey Hill, Mount Hope Station.

Although the specimen is not perfectly preserved the tubuli of the peripheral margin are lacking as is the case in some large recent specimens.

Family NUMMULITIDAE.

Genus NONIONINA d'Orbigny, 1826.

NONIONINA DEPRESSULA (Walker and Jacob).

Plate 25, figs. 5*a*, *b*.

Nautilus depressulus Walker and Jacob, Adam's Essays, Kanmacher ed., 1798, p. 641, pl. 14, fig. 33.

Nonionina depressula Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 1859, pp. 339, 341.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, v 9, 1884, p. 725, pl. 109, figs. 6, 7.—Bagg, Bull. U. S. Geol. Surv., No. 5 1912, p. 88, pl. 26, figs. 16*a–c*; pl. 28, figs. 7, 8.

Description.—Test more or less rounded in side view, slightly elongate, about ten chambers in the last formed coil, apertural vie narrow, periphery broadly rounded, sides nearly parallel, about tw and a half times as high as broad, umbilicus slightly depresse

sually filled with secondary shell material and a slight extension eripherally along the sutures which are slightly depressed; aperture a narrow curved slit.

Diameter 0.60 mm. Cat. Nos. 324680–1, U.S.N.M.

Distribution.—Specimens of this species occurred in the Gatun ormation at U.S.G.S. No. 6033*c*, in marl from second bed from ottom, just below lower clay, Gatun Section, relocated line of the 'anama Railroad; and 6035, in gray green, fine grained, sandy shell iarl, vicinity of Mindi Hill. The specimens are rather typical, peraps varying in the direction of increased length from most recent pecimens.

NONIONINA SCAPHA (Fitchel and Moll).

Plate 25, figs. 6*a*, *b*.

Nautilus scapha Fichtel and Moll, Test. Micr., 1803, p. 105, pl. 19, figs. *d–f*.

Nonionina scapha Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 5, 1860, p. 102, No. 4.—H. B. Brady, Nat. Hist. Trans. Northumberland and Durham, vol. 1, 1865, p. 106, pl. 12, figs. 10*a*, *b*.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 730, pl. 109, figs. 14, 15, and 16.—H. B. Brady, Parker, and Jones, Trans. Zool. Soc., vol. 12, 1888, p. 230, pl. 43, fig. 20.—Woodward and Thomas, Geol. Nat. Hist. Surv. Minnesota, vol. 3, 1893, p. 48, pl. E, figs. 35, 36.—Egger, Abh. kön. Bay. Akad. Wiss. München, Cl. II, vol. 18, 1893, p. 424, pl. 19, figs. 43, 44.—Goës, Kongl. Svensk. Vet. Akad. Handl., vol. 25, 1894, p. 104, pl. 17, fig. 830.—Morton, Proc. Portland Soc. Nat. Hist., vol. 2, 1897, p. 121, pl. 1, fig. 23.—Flint, Ann. Rep. U. S. Nat. Mus., 1897 (1899), p. 337, pl. 80, fig. 1.—Fornasini, Mem. Accad. Sci. Ist. Bologna, ser. 6, vol. 1, 1904, p. 12, pl. 3, fig. 4; pl. 13, fig. 5.—Millett, Journ. Roy. Micr. Soc., 1904, p. 601.—Bagg, Proc. U. S. Nat. Mus., vol. 34, 1908, p. 164.—Sidebottom, Mem. and Proc. Manchester Lit. and Philos. Soc., vol. 53, No. 21, 1909, p. 13; vol. 54, No. 16, 1910, p. 29, pl. 3, fig. 13.—Bagg, Bull. U. S. Geol. Surv. No. 513, 1912, p. 88, pl. 27, figs. 1–3.

Polystomella crispa, var. (*Nonionina*) *scapha* Parker and Jones, Philos. Trans., vol. 155, 1865, p. 404, pl. 14, figs. 37, 38; pl. 17, figs. 55, 56.

Description.—Test in side view longer than wide, about ten chambers in the last formed coil, rapidly increasing in length as added, utures evenly curved, slightly depressed, periphery broadly rounded, n apertural view the face of the last formed chamber making up a arge part of the visible surface, wall smooth, finely punctate, somewhat umbilicate; aperture an arched slit at the base of the chamber.

Length 0.60 mm. Cat. No. 324682, U.S.N.M.

Specimens of this species were collected in the Gatun formation t a single station, U.S.G.S. No. 6033*c*, in marl from second bed rom bottom, just below lower clay, Gatun section, relocated line of he Panama Railroad.

The specimen figured in apertural view was placed to show the perture rather than the full size of the apertural face which is really

larger than appears in this view, the earlier portion of the coil being narrow.

NONIONINA PANAMENSIS, new species.

Plate 26, figs. 1*a*, *b*.

Description.—Test in side view subcircular, last formed chamber composed of about nine chambers, in front view bilaterally symmetrical, rapidly increasing in breadth as chambers are added, apertural face of chamber broadly rounded, early portion slightly keeled; sutures rather strongly curved, slightly limbate, slightly depressed; wall smooth, distinctly punctate; aperture a narrow curved slit at the base of the apertural face of the chamber.

Diameter 0.65 mm.

Specimens of this species were obtained from the lower part of the Culebra formation, U.S.G.S. No. 6010, north of Pedro Miguel Locks, in dark clay.

Type-specimen.—Cat. No. 324683, U.S.N.M.

NONIONINA ANOMALINA, new species.

Plate 26, figs. 2*a*, *b*.

Description.—Test in side view nearly circular, deeply umbilicate, peripheral margin broadly rounded, bilaterally symmetrical, about seven chambers in the last formed coil, sutures little if at all depressed, indistinct, last formed chambers extending but part way across the test, tending toward alternating arrangement; aperture a narrow slit at the base of the chamber.

Diameter 1.25 mm.

Type-specimen.—(Cat. No. 324684, U.S.N.M.) from the lower part of the Culebra formation, in dark clay, north of Pedro Miguel Locks (U.S.G.S. No. 6010).

The last two chambers suggest *Cassidulina*, but the similarity does not continue further.

Genus POLYSTOMELLA Lamarck, 1822.

POLYSTOMELLA STRIATO-PUNCTATA (Fitchel and Moll).

Plate 26, figs. 3*a*, *b*; 4*a*, *b*.

Nautilus striato-punctatus Fichtel and Moll, Test. Micr., 1803, p. 61, pl. 9, figs. *a–c*.

Polystomella striato-punctata Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 5, 1860, p. 103, No. 6.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 733, pl. 109, figs. 22, 23.

Description.—Test bilaterally symmetrical, subcircular in side view, umbilicate, peripheral margin broadly rounded, eight to ten chambers

in the last formed coil; sutures slightly curved, depressed; wall smooth, distinctly punctate; septal lines with regularly arranged, narrow bridging; aperture a narrow semicircular opening at the base of the apertural face of the chamber, showing occasionally traces of division into a series of smaller openings.

Diameter 0.50 to 0.65 mm. Cat Nos. 324685–7, U.S.N.M.

Specimens were obtained in the Culebra formation, U.S.G.S. No. 6020*a*, opposite Las Cascadas, in lowest fossiliferous bed, third bed below lowest limestone. These were very largely glauconitic, and of the form figured in 4*a*, *b*. The species was also found in the Gatun formation, U.S.G.S. No. 6029*a*, one-fourth to one-half mile north of Camp Cotton, relocated line of the Panama Railroad, in the softer sandy marls at the base of the section. The form figured in 3*a*, *b*, is from a Pleistocene deposit at U.S.G.S. No. 5850, loose shells and marl from near Mount Hope, one-fourth mile from present beach, 6 to 8 feet above high tide.

POLYSTOMELLA SAGRA d'Orbigny.

Plate 26, figs. 5*a*, *b*.

Polystomella Sagra D'ORBIGNY, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, Foraminifères, p. 55, pl. 6, figs. 19, 20.

Description.—Test bilaterally symmetrical, subcircular in side view; peripheral margin rounded, ten or more chambers in the last formed coil; sutures distinct, curved, slightly depressed in the last formed portion, not at all depressed in the early part of the coil; early half of the coil with definite raised, longitudinal ribs, corresponding to the bridging over the sutures, persisting longest on the peripheral portion of the test, later portion smooth; bridging of earliest portion of coil regular, short, in the last formed sutures increasing considerably in length; apertural face smooth, punctate; roughly triangular in outline, the angles rounded; aperture a very narrow slit at the base of the apertural face of the chamber.

Diameter 0.65 mm. Cat. No. 324688, U.S.N.M.

The only station at which this species was obtained is a Pleistocene deposit at U.S.G.S. No. 5850, loose shells and marl from near Mount Hope, one-fourth mile from present beach and 6 to 8 feet above high tide.

A comparison of this figure with the original given by d'Orbigny in his Cuba monograph will show the very striking similarity between the Cuba and Panama specimens, and I have no hesitation in referring this material to d'Orbigny's species.

POLYSTOMELLA MACELLA (Fichtel and Moll).

Plate 27, figs. 1*a*, *b*.

Nautilus macellus, var. *a*, Fichtel and Moll, Test. Micr., 1803, p. 66, pl. 10 figs. *e–g*.

Polystomella macella Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 5 1860, p. 104, No. 8.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9 1884, p. 737, pl. 110, figs. 8, 9, 11.

Description.—Test compressed, bilaterally symmetrical, peripher margin acute, somewhat carinate, not lobulated, sixteen to twent chambers in the last formed coil; reticulated bridgings occupying greater area than the intermediate portions; umbilical region slightl depressed, with a few large pores; aperture a curved or V-shape slit at the base of the apertural face, either simple or divided int secondary openings.

Diameter, 0.75 mm. Cat. Nos. 324689–90, U.S.N.M.

Specimens were obtained from two stations in the Emperad limestone, as follows: U.S.G.S. 6015, from cream-colored coral lim stone, old quarry one-quarter mile north of west from Empire; an 6016, one-third mile north of west of the same place.

POLYSTOMELLA CRISPA (Linnaeus).

Plate 27, figs. 2*a*, *b*.

"Cornu Hammonis orbiculatum" Plancus, Conch. Min., 1739, p. 10, pl. fig. 2.

Nautilus crispus Linnaeus, Syst. Nat., ed. 12, 1767, p. 1162.

Polystomella crispa Lamarck, Anim. sans Vert., vol. 7, 1822, p. 625, No. 1. d'Orbigny, Foram. Foss. Bass. Tert. Vienne, 1846, p. 125, pl. 6, figs. 14.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 7 pl. 110, figs. 6, 7.

Description.—Test bilaterally symmetrical, much compressed, p ripheral margin obtusely angled; umbilical region not depresse chambers numerous, eighteen to twenty chambers in the last form coil, sutures indistinct, bridging wider than the intermediate cle space; margin not lobulated; umbilical region umbonate, filled w clear shell material, often with a few pores; aperture a narrow s at the base of the apertural face of the chamber, usually showi more or less division into secondary openings.

Diameter, up to 1.25 mm. Cat. No. 324691, U.S.N.M.

Specimens referable to this species were obtained from the Gat formation at U.S.G.S. No. 6029*b*, one-fourth to one-half mile no of Camp Cotton on relocated line of the Panama Railroad, indura argillaceous and sandy marl.

POLYSTOMELLA CRATICULATA (Fichtel and Moll).

Plate 27, figs. 3*a*, *b*.

Nautilus craticulatus Fichtel and Moll. Test. Micr., 1803, p. 51, pl. 5, figs. *h–k*.

Polystomella craticulata d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 284, No. 3.—Carpenter, Intr. Foram., 1862, p. 279, pl. 16, figs. 1, 2.—H. B. Brady. Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 739, pl. 110, figs. 16, 17.

Description.—Test bilaterally symmetrical, somewhat compressed; peripheral margin broadly rounded; not lobulated, chambers very numerous, forty or more in the last formed coil, narrow; umbilical region filled with clear shell material with numerous pores; bridged area about equal to that between; aperture a series of openings at the base of the apertural face.

Diameter, 1 mm. Cat. No. 324692, U.S.N.M.

This species was found in considerable numbers in the Culebra formation at U.S.G.S. No. 6025, in foraminiferal marl and coarse sandstone about 200 yards south of the southern end of the switch at Bohio Ridge station, relocated line, Panama Railroad.

The specimens have not as subglobose a form as many recent specimens, but in other respects the characters are very similar.

POLYSTOMELLA, species?

Numerous stations have a species of *Polystomella* which is very much like *P. sagra* and yet is not so definitely characterized as are the specimens of that species from station 6025.

The stations at which this form of *Polystomella* occurs are in the lower part of the Culebra formation at U.S.G.S. No. 6009, black clays, six or seven hundred feet south of Miraflores Locks. In Las Cascadas section, Gaillard Cut, 6019*b*, from the 4 feet of dark stratified tuff and clay overlying the lower limestone bed; 6019*f*, from fourth limy bed from bottom; 6020*a*, from the lowest fossiliferous bed. In the Emperador limestone at 6015 and 6016 from cream-colored coral limestone, old quarry, one-quarter mile north of west from Empire. In the Gatun formation at 6029*a*, from lowest horizon, one-fourth to one-half mile north of Camp Cotton.

Cat. Nos. 324693–8, U.S.N.M.

Genus AMPHISTEGINA d'Orbigny, 1826.

AMPHISTEGINA LESSONII d'Orbigny.

Amphistegina lessonii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 304, No. 3, pl. 17, figs. 1–4; Modèles, No. 98.—H. B. Brady. Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 740, pl. 111, figs. 1–7.

Description.—Test lenticular, usually more convex on one side than the other; composed of about twenty-five chambers in the last formed

coil, wall smooth except near the aperture on the ventral side where there is usually a papillose area of greater or less extent; periphery usually somewhat rounded; sutures on the dorsal side with a single simple angle; below usually divided into two deep lobes by deep constrictions.

Diameter, 1–2.5 mm. Cat. Nos. 324699–08, U.S.N.M.

This species is common in the lower horizons of the area occurring at the following stations: Culebra formation, 6009, 6012*a*, *d*, 6019*c*, *d* 6027; Emperador limestone, 6015, 6016; Gatun formation, 6029*a*, *b*, *c*

At some of these stations specimens are rather frequent. In the matrix this species may often be indistinguishable in a superficial examination from worn centers of Orbitoids or Nummulites. It is a common Tertiary species.

Family MILIOLIDAE.

Genus QUINQUELOCULINA d'Orbigny, 1826.

QUINQUELOCULINA SEMINULUM (Linnaeus).

Plate 27, figs. 4*a*, *b*; plate 28; plate 29, figs. 1*a–e*.

Serpula seminulum Linnaeus, Syst. Nat., ed. 10, 1758, p. 786; ed. 1 (Gmelin), 1758, pp. 37, 39.

Quinqueloculina seminulum d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 30 No. 44.

Miliolina seminulum Williamson, Rec. Foram. Great Britain, 1858, p. 8 pl. 7, figs. 183–189.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 1884, p. 157, pl. 5, figs. 6*a*, *b*, *c*.

Description.—Test oval in front view; thickest in the middl visible exterior composed of five chambers, three visible from or side and four from the other, sutures slightly depressed, distinc wall smooth, periphery rounded, aperture somewhat contracte usually with a single simple tooth.

Length about 1 mm. Cat. Nos. 324709–13, U.S.N.M.

Very typical specimens were obtained from U.S.G.S. No. 585 among loose shells and marl from near Mount Hope, from dit through swampy ground, one-fourth mile from present sea beach ar 6 to 8 feet above high tide (Pleistocene). Specimens very simil but slightly more rotund were obtained from the Gatun formatio No. 6036, in dark colored, fine grained, sandy clay marl, at Monk Hill, Mount Hope Station.

Varietal forms here figured and which may be referred to *Q. sem nulum* were obtained from the Culebra formation at No. 6010, fro dark clay, north of Pedro Miguel Locks; 6019*a*, a single specim from lower limestone of Las Cascadas section; 6025, a single gla conitic specimen from foraminiferal marl about 200 yards south

southern end of switch at Bohio Ridge Station, relocated line of the Panama Railroad. Another much flattened glauconitic specimen from this last station is also referred here.

QUINQUELOCULINA CONTORTA d'Orbigny.

Plate 29, figs. 2*a–c*.

Quinqueloculina contorta d'Orbigny, Foram. Foss. Bass. Tert, Vienne, 1846, p. 298, pl. 20, figs. 4–6.

Description.—Test about twice as long as broad, chambers rather narrow and elongate, in end view polygonal, peripheral margin broadly curved, sides nearly at right angles to the peripheral face with a sharp angle at the junction; sutures deep, apical end and initial end of final chamber truncated; aperture rounded with a single tooth; wall smooth.

Length 0.65 mm. Cat. No. 324714, U.S.N.M.

The only material of this species was obtained from U.S.G.S. 5850, among loose shells and marl, from near Mount Hope, from ditch through swampy ground, about one-fourth mile from present sea beach and 6 to 8 feet above high tide (Pleistocene).

QUINQUELOCULINA AUBERIANA d'Orbigny.

Plate 29, figs. 3*a–c*.

Quinqueloculina auberiana d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, Foraminifères, p. 193, pl. 12, figs. 1–3.

Miliolina auberiana H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 162, pl. 5, figs. 8, 9.

Description.—Test slightly longer than broad, periphery of the chambers angled with a concave area at each side of the angle, sutures somewhat depressed, distinct; wall smooth; aperture with a single, usually simple, occasionally slightly bifid tooth.

Length about 1 mm. Cat. No. 324715, U.S.N.M.

Two specimens of this species were obtained in material from U.S.G.S. 5850, among loose shells and marl, from near Mount Hope, from ditch through swampy ground, about one-fourth mile from present sea beach and 6 to 8 feet above high tide (Pleistocene). This is a common species of the shallow-water littoral of tropical seas.

QUINQUELOCULINA UNDOSA Karrer.

Plate 30, figs. 1*a–c*.

Quinqueloculina undosa Karrer, Sitz. Akad. Wiss. Wien, vol. 58, abth. 1, 1868, p. 150, pl. 3, fig. 1.

Miliolina undosa Karrer, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 176, pl. 6, figs. 6–8.

Description.—Test elongate, two or two and a half times as long as wide; chambers sub-polygonal, the angles more or less irregular giv-

ing an undulate appearance to the chambers, apertural end typically with a slightly projecting neck, aperture with a single tooth; wall smooth.

Length 1.25 mm. Cat. Nos. 324716–17, U.S.N.M.

Specimens referable to this species were obtained in the Emperador limestone, at U.S.G.S. 6016, from old quarry, one-third mile north of west of Empire; and in the Culebra formation, at 6025, in foraminiferal marl about 200 yards south of the southern end of the switch at Bohio Ridge Station, relocated line, Panama Railroad.

The specimens are not so contorted as in some recent ones but show characteristic undulations of the chamber borders.

QUINQUELOCULINA BICORNIS (Walker and Jacob).

Plate 30, figs. 2*a–c*; 3*a*, *b*.

"Serpula bicornis ventricosa," Walker and Boys, Test. Min., 1784, p. [illegible] pl. 1, fig. 2.

"Frumentaria *foeniculum*" Soldani, Testaceographia, vol. 1, pt. 3, 179[illegible] p. 229, pl. 154, figs. *bb*, *cc*.

Serpula bicornis Walker and Jacob, Adams's Essays, Kanmacher's ed. 1798, p. 633, pl. 14, fig. 2.

Miliolina bicornis Williamson, Rec. Foram. Great Britain, 1858, p. 87, [illegible] 7, figs. 190–192.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 1884, p. 171, pl. 6, figs. 9, 11, 12.

Description.—Test in side view about twice as long as wide, sutures rather deep, distinct, chambers more or less keeled, wall ornamented with numerous rather fine longitudinal raised costae, aperture slightly exserted, rounded, with a single tooth.

Length 0.75 mm. Cat. Nos. 324718–9, U.S.N.M.

Specimens were obtained in a Pleistocene deposit at U.S.G.S. 5855 among loose shells and marl, from near Mount Hope, from ditch through swampy ground about one-fourth mile from present sea beach, and 6 to 8 feet above high tide.

From the Culebra formation, U.S.G.S. 6025, in foraminiferal marl about 200 yards south of southern end of switch at Bohio Ridge Station, relocated line, Panama Railroad, were obtained, rather poorly preserved and somewhat glauconitic specimens, but showing traces of a longitudinal series of raised ridges. They are questionably referred here and one is figured, on plate 30, figure 3.

QUINQUELOCULINA PANAMENSIS, new species.

Plate 31, figs. 1*a–c*.

Description.—Test nearly as wide as long, the last formed chamber tending to become loose coiled, growing away from the preceding ones on the apertural half of the inner margin, apertural end fr[illegible]

peripheral margin broadly rounded, sutures much depressed; wall smooth; aperture circular.

Length 0.85 mm.

This species was obtained from the Gatun formation, U.S.G.S. 6036, in dark colored, fine grained, sandy clay marl, from Monkey Hill, Mount Hope Station.

It is unusual in the breaking away of the last formed chamber from the original close coiled method of growth.

Type-specimen.—Cat. No. 324720, U.S.N.M.

Genus SIGMOILINA Schlumberger, 1887.

SIGMOILINA TENUIS (Czjzek).

Plate 31, figs. 4*a–c*.

Quinqueloculina tenuis Czjzek, Haidinger's Nat. Abhandl., vol. 2, 1847, p. 149, pl. 13, figs. 31–34.

Spiroloculina tenuis H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 152, pl. 10, figs. 7–11.

Sigmoilina tenuis Sidebottom, Mem. and Proc. Manchester Lit. and Philos. Soc., vol. 48, No. 5, 1904, p. 6.

Description.—Test about twice as long as wide, narrow, compressed, visible chambers 5 or 6 on either side, chambers narrow, rounded, sutures depressed, distinct; wall smooth, aperture exserted, rounded.

Length 0.65 mm. Cat. Nos. 324721–3, U.S.N.M.

Specimens of this species were obtained in the Gatun formation at the following three stations: U.S.G.S. 6033*c*, in marl from second bed from bottom, just below lower clay, Gatun section, relocated line of the Panama Railroad; 6035, in gray green, fine grained, sandy shell marl, vicinity of Mindi Hill; and 6036, in dark colored, fine grained, sandy clay marl, from Monkey Hill, Mount Hope Station.

These three stations have several species in common as will be seen by a glance at the accompanying chart of distribution.

SIGMOILINA ASPERULA (Karrer).

Plate 31, figs. 3 *a*, *b*.

Spirolucina asperula Karrer, Sitz. Akad. Wiss. Wien, vol. 57, 1868, p. 136, pl. 1, fig. 10.—H. B. Brady, Rep. Vol. *Challenger*, Zoology, vol. 9, 1884, p. 152, pl. 8, figs. 13, 14, and 11.

Description.—Test but slightly longer than wide, very much compressed, sutures somewhat indistinct, several chambers visible from each of the flattened sides; wall covered with fine arenaceous particles; aperture exserted, nearly circular.

Length, 0.8 mm. Cat. Nos. 324724–5, U.S.N.M.

Specimens were not uncommon in the Gatun formation at tw stations, U.S.G.S. 6035, in gray green, fine grained, sandy shell mar vicinity of Mindi Hill, and 6036, in dark colored, fine grained, sand clay marl, from Monkey Hill, Mount Hope Station.

Genus TRILOCULINA d'Orbigny, 1826.

TRILOCULINA TRIGONULA (Lamarck).

Plate 32, fig. 1.

Miliolites trigonula LAMARCK, Ann. Mus., vol. 5, 1804, p. 351, No. 3.
Triloculina trigonula D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 299, No. pl. 16, figs. 5–9.
Miliolina trigonula WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 8 pl. 7, figs. 180–182.—H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 1884, p. 164, pl. 3, figs. 14–16.

Description.—Test in apertural view triangular, angles rounde chambers rapidly increasing in size as added, but three visible adult test; outer wall broadly rounded, in front view oval, sutur distinct, aperture not produced, lip and tooth indistinct.

Length, 0.75 mm. Cat. No. 324726, U.S.N.M.

A single specimen referable to this species occurred at U.S.G. 5850, in Pleistocene marly material from near Mount Hope, on fourth mile from present sea beach and about 6 to 8 feet above hig tide.

This is a common species in shallow water of recent oceans.

TRILOCULINA TRICARINATA d'Orbigny.

Plate 32, fig. 2.

Triloculina tricarinata D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 299, No. ; Modèles, No. 94.—H. B. BRADY, Trans. Linn. Soc. London, vol. 24, 18 p. 446, pl. 48, fig. 3.
Miliolina tricarinata H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 1884, p. 165, pl. 3, figs. 17*a*, *b*.

Description.—Test differing from *T. trigonula* largely in the a gles, which are acute, the sides concave, at least toward the borde center of the side either flat or slightly convex, in end view ratl sharply triangular, in front view oval; neck slightly produced, ap ture rounded, tooth wanting in this specimen.

Length, 0.60–0.70 mm.

Four specimens were collected in the Culebra formation at U.S.G No. 6025, foraminiferal marl about 200 yards south of southern e of switch at Bohio Ridge Station, relocated line, Panama Railro

Two of the four specimens had the neck somewhat elongated, th others were more nearly normal in this respect. The specimens w

somewhat altered and showed traces of apparently a glauconitic interior.

TRILOCULINA BULBOSA, new species.

Plate 32, fig. 3.

Description.—Test from exterior composed of three visible chambers, the last formed one making the largest part of the test. The next to the last about half the size of the last and the first formed one very small in comparison, test in end view nearly biloculine, with the last formed chamber nearly as wide as the whole test in its greatest width, in front view breadth and height about equal, chambers very rotund, sutures deep, aperture without a neck, rounded, tooth indistinct or wanting.

Length, about 0.65 mm.

Type-specimen.—(Cat. No. 324728, U.S.N.M.) from the Gatun formation, U.S.G.S. Station 6029*a*, lowest horizon, one-fourth to one-half mile north of Camp Cotton on relocated line Panama Railroad. Another specimen was obtained, also in the Gatun formation, at No. 6030, from fossiliferous marl, from cut on north side of swamp 1½ miles north of Monte Lirio, relocated line of the Panama Railroad.

In each case a single somewhat glauconitic specimen was obtained. The species has the last two chambers developed greatly, the third one very small, the whole test appearing almost biloculine. The specimens from the two stations were practically identical.

TRILOCULINA PROJECTA, new species.

Plate 33, fig. 1.

Description.—Test in end view composed of three radially projecting portions, the intervening portions deeply concave, in side view about as long as wide, sutures somewhat indistinct, periphery broadly rounded; wall covered with a thick encrustation of sand grains giving the whole exterior a decidedly arenaceous appearance; aperture with a slightly projecting neck and phialine lip; apertural opening circular, in the specimen figured without a distinct tooth.

Length 0.75 mm.

Type-specimen.—(Cat. No. 324729, U.S.N.M.) From gray green, fine grained, sandy shell marl from vicinity of Mindi Hill, U.S.G.S. No. 6035, Gatun formation.

This is an interesting modification of this genus, comparable in the structure of the test to *Quinqueloculina agglutinans* d'Orbigny and others of the same character.

Genus BILOCULINA d'Orbigny, 1826.

BILOCULINA BULLOIDES d'Orbigny.

Plate 33, fig. 2.

Biloculina bulloides d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 297, No. pl. 16, figs. 1–4; Modèles, No. 90.—H. B. Brady, Rep. Voy. *Challeng* Zoology, vol. 9, 1884, p. 142, pl. 2, figs. 5, 6

Description.—Test with but two visible chambers in the adult, end view, each semicircular, in front view elliptical, very rotun inflated, suture distinct; aperture usually nearly circular, somewh produced.

Length 0.60 mm. Cat. No. 324730, U.S.N.M.

The only specimen of this species is from the Gatun formatic U.S.G.S. 6036, from dark colored, fine grained, sandy clay marl fr Monkey Hill, Mount Hope Station.

Genus SPIROLOCULINA d'Orbigny, 1826.

SPIROLOCULINA EXCAVATA d'Orbigny.

Plate 31, fig. 2.

Spiroloculina excavata d'Orbigny, Foram. Foss. Bass. Tert. Vienne, 18 p. 271, pl. 16, figs. 19–21.—H. B. Brady, Rep. Voy. *Challenger*, Zoolo vol. 9, 1884, p. 151, pl. 9, figs. 5, 6.

Description.—Test planospiral, chambers much elongated, thick at the basal end, apertural end slightly produced, central porti much excavated, due to the gradual increase in the width of chambers as added; periphery somewhat convex, angles round sutures distinct except toward the center; apertural end produc aperture rounded; tooth wanting in our specimen.

Length 1.4 mm. Cat. No. 324731, U.S.N.M.

Specimens were obtained at Station No. 5850, in marl of Pleis cene, Mount Hope, Canal Zone, by D. F. MacDonald.

Genus ORBICULINA Lamarck, 1816.

ORBICULINA ADUNCA (Fichtel and Moll).

Plate 33, fig. 3.

Nautilus orbiculus Fichtel and Moll, Test. Micr., 1803, p. 112, pl. 21.
Orbiculina adunca Lamarck, Tabl. Encycl. et Méth., 1816, pl. 468, 2*a–c*.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. pl. 14, figs. 1–13.

Description.—Test planospiral, chambers very long, divided to simple chamberlets, sides with alar projections extending nearly to the umbilicus, sutures distinct; apertures numerous, peripheral.

Diameter 1.6 mm. Cat. No. 324732, U.S.N.M.

A few specimens were obtained from U.S.G.S. 5850, from Pleistocene marl near Mount Hope, about one-fourth mile from present sea beach and about 6 to 8 feet above high tide.

EXPLANATION OF PLATES.

PLATE 19.

FIG. 1. *Textularia abbreviata* d'Orbigny. × 50. *a*, apertural view; *b*, front view.
2. *Textularia sagittula* Defrance. × 30. *a*, apertural view; *b*, front view.
3. *Textularia agglutinans* d'Orbigny. × 50. *a*, apertural view; *b*, front view.
4. *Textularia laminata*, new species. × 30. *a*, apertural view; *b*, front view.
5. *Textularia subagglutinans*, new species. × 35. *a*, apertural view; *b*, front view.
6. *Textularia carinata* d'Orbigny. × 50. *a*, apertural view; *b*, front view.

PLATE 20.

FIG. 1. *Textularia panamensis*, new species. × 65. *a*, aperture view; *b*, front view.
2. *Chrysalidina pulchella*, new species. × 110. *a*, apertural view; *b*, viewed from flat side; *c*, viewed from angle.
3. *Gaudryina triangularis* Cushman. × 35. *a*, apertural view; *b*, front view.
4. *Gaudryina flintii* Cushman. × 50.
5. *Clavulina parisiensis* d'Orbigny. × 35.
6. *Clavulina communis* d'Orbigny. × 35.

PLATE 21.

1. *Bolivina*, species. × 65.
2. *Bolivina aenariensis* (Costa). × 65.
3. *Bolivina* cf. B. *punctata* d'Orbigny. × 65.
4. *Bolivina robusta* H. B. Brady. × 135.
5. *Bigenerina nodosaria* d'Orbigny. × 27. *a*, apertural view; *b*, front view.
6. *Virgulina squamosa* d'Orbigny. × 65.
7. *Lagena striata* (d'Orbigny), var. *strumosa* Reuss. × 65.
8. *Nodosaria communis* d'Orbigny. × 65.
9. *Nodosaria* cf. *N. insecta* Schwager. × 35.
10. *Nodosaria raphanistrum* (Linnaeus). × 35.
11. *Nodosaria*, species ? × 35.

PLATE 22.

1. *Cristellaria rotulata* (Lamarck). × 35.
2. *Cristellaria protuberans*, new species. × 65.
3. *Cristellaria vaughani*, new species. × 65.
4. *Uvigerina pygmaea* d'Orbigny. × 65.
5. *Uvigerina canariensis* d'Orbigny. × 65.
6. *Uvigerina canariensis* d'Orbigny var. × 65.
7. *Uvigerina tenuistriata* Reuss. × 65.
8. *Siphogenerina raphanus* (Parker and Jones) var. *transversus*, new variety. × 35.

PLATE 23.

FIG. 1. *Discorbis obtusa* (d'Orbigny). *a*, dorsal view; *b*, ventral view; *c*, p
ripheral view. × 65.
2. *Truncatulina americana*, new species. *a*, dorsal view; *b*, ventral vie
c, peripheral view. × 65.
3. *Truncatulina pygmea* Hantken. *a*, dorsal view; *b*, ventral view; *c*, p
ripheral view. × 65.

PLATE 24.

FIG. 1. *Truncatulina ungeriana* (d'Orbigny.) × 65.
2. *Truncatulina* cf. *T. pygmea* Hantken. × 33.
3. *Truncatulina wuellerstorfi* (Schwager). × 50.
4. *Truncatulina culebrensis*, new species. × 33. *a*, dorsal view; *b*,
ripheral view.
5. *Siphonina reticulata* (Czjzek). × 65.
6. *Pulvinulina sagra* (d'Orbigny). × 65. *a*, dorsal view; *b*, ventral vi

PLATE 25.

FIG. 1. *Pulvinulina concentrica* Parker and Jones. × 35.
2. *Pulvinulina menardii* (d'Orbigny). × 65.
3. *Pulvinulina menardii* (d'Orbigny). × 65.
4. *Pulvinulina*, species ? × 65.
5. *Nonionina depressula* (Walker and Jacob). × 65. *a*, side view;
apertural view.
6. *Nonionina scapha* (Fichtel and Moll). × 65. *a*, side view; *b*, ap
tural view.

PLATE 26.

FIG. 1. *Nonionina panamensis*, new species. × 65. *a*, side view; *b*, apertu
view.
2. *Nonionina anomalina*, new species. × 65. *a*, side view; *b*, apertu
view.
3. *Polystomella striato-punctata* (Fichtel and Moll). × 65. *a*, side vi
b, apertural view.
4. *Polystomella striato-punctata* (Fichtel and Moll). × 65. *a*, side vi
b, apertural view.
5. *Polystomella sagra* d'Orbigny. × 65. *a*, side view; *b*, apertural v

PLATE 27.

FIG. 1. *Polystomella macella* (Fichtel and Moll). × 65. *a*, side view; *b*, a
tural view.
2. *Polystomella crispa* (Linnaeus). × 35. *a*, side view; *b*, apertural v
3. *Polystomella craticulata* (Fichtel and Moll). × 50. *a*, side view *b*
apertural view.
4. *Quinqueloculina seminulum* (Linnaeus). × 65. *a*, rear view; *b*, a
tural view.

PLATE 28.

FIG. 1. *Quinqueloculina seminulum* (Linnaeus). × 65. *a*, front view; *b*, rear view; *c*, apertural view.
2. *Quinqueloculina seminulum* (Linnaeus). × 130. *a*, front view; *b*, rear view; *c*, apertural view.
3. *Quinqueloculina seminulum* (Linnaeus) var. × 65. *a*, front view; *b*, rear view; *c*, apertural view.

PLATE 29.

FIG. 1. *Quinqueloculina seminulum* (Linnaeus) var. × 80. *a*, front view; *b*, rear view; *c*, apertural view.
2. *Quinqueloculina contorta* d'Orbigny. × 65. *a*, front view; *b*, rear view; *c*, apertural view.
3. *Quinqueloculina auberiana* d'Orbigny. × 65. *a*, front view; *b*, rear view; *c*, apertural view.

PLATE 30.

FIG. 1. *Quinqueloculina undosa* Karrer. × 50. *a*, front view; *b*, rear view; *c*, apertural view.
2. *Quinqueloculina bicornis* (Walker and Jacob). × 65. *a*, front view; *b*, rear view; *c*, apertural view.
3. *Quinqueloculina bicornis* (Walker and Jacob)?. × 50. *a*, front view; *b*, rear view.

PLATE 31.

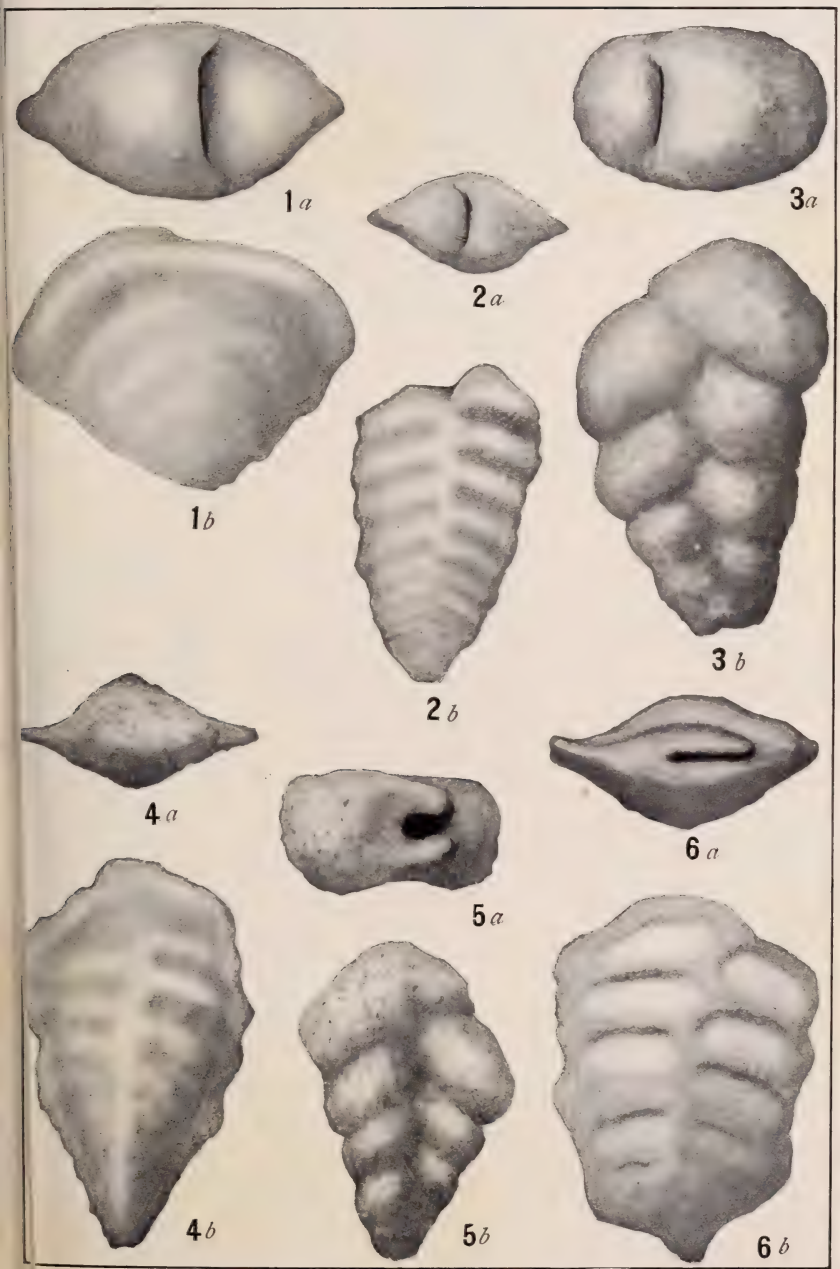
FIG. 1. *Quinqueloculina panamensis*, new species. × 65. *a*, front view; *b*, rear view; *c*, apertural view.
2. *Spiroloculina excavata* d'Orbigny. × 40. *a*, front view; *b*, apertural view.
3. *Sigmoilina asperula* (Karrer). × 65. *a*, front view; *b*, apertural view.
4. *Sigmoilina tenius* (Czjzek). × 65. *a*, front view; *b*, rear view; *c*, apertural view.

PLATE 32.

FIG. 1. *Triloculina trigonula* (Lamarck). × 65. *a*, front view; *b*, side view; *c*, apertural view.
2. *Triloculina tricarinata* d'Orbigny. × 65. *a*, rear view; *b*, side view; *c*, apertural view.
3. *Triloculina bulbosa*, new species. × 65. *a*, rear view; *b*, side view; *c*, apertural view.

PLATE 33.

FIG. 1. *Triloculina projecta*, new species. × 65. *a*, front view; *b*, rear view; *c*, apertural view.
2. *Biloculina bulloides* d'Orbigny. × 65. *a*, front view; *b*, side view; *c*, apertural view.
3. *Orbiculina adunca* (Fichtel and Moll). × 30.



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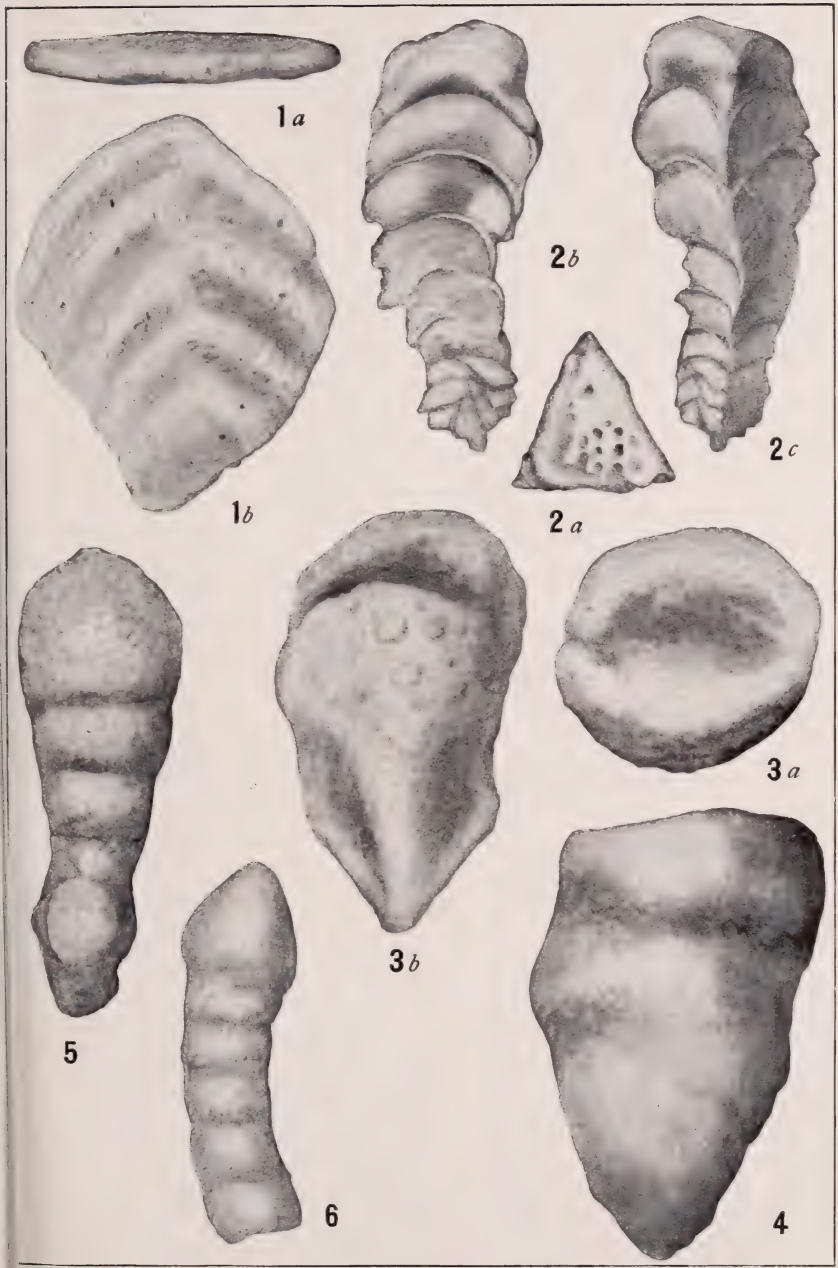

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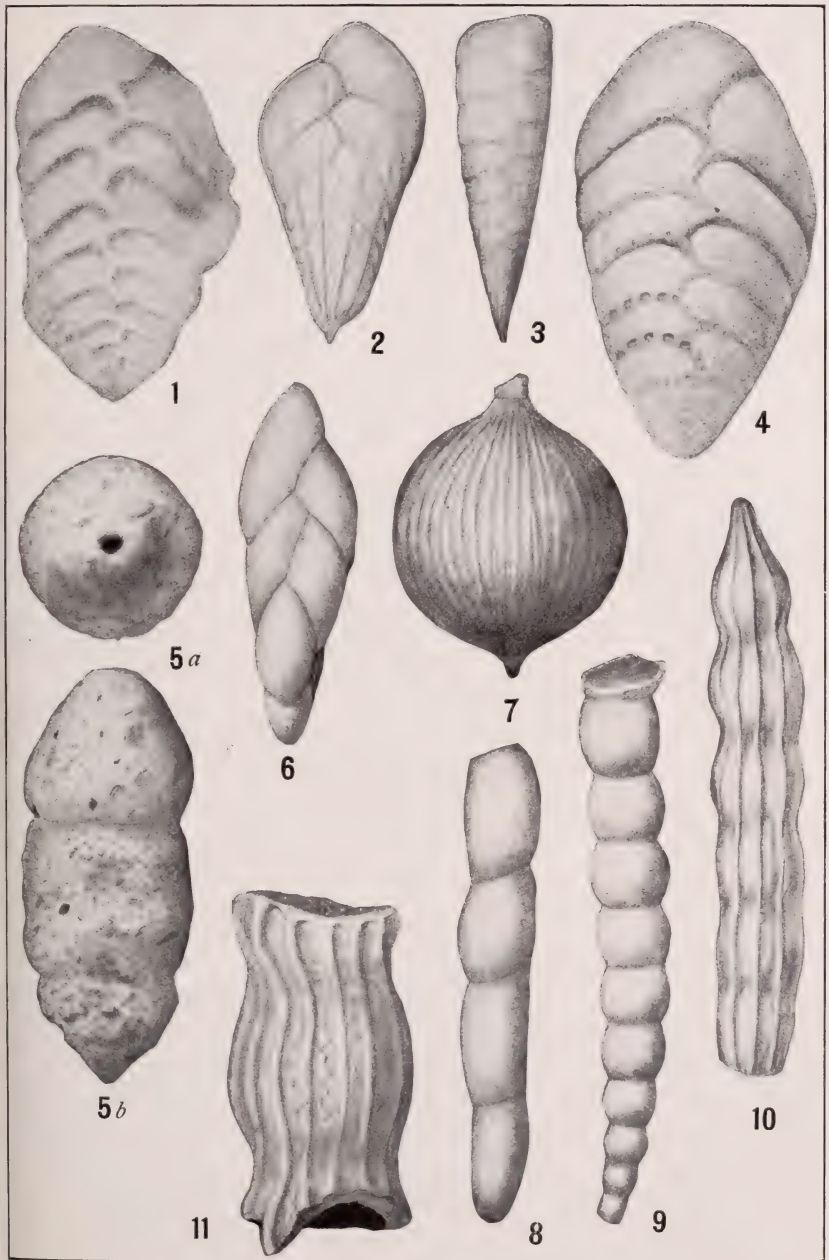

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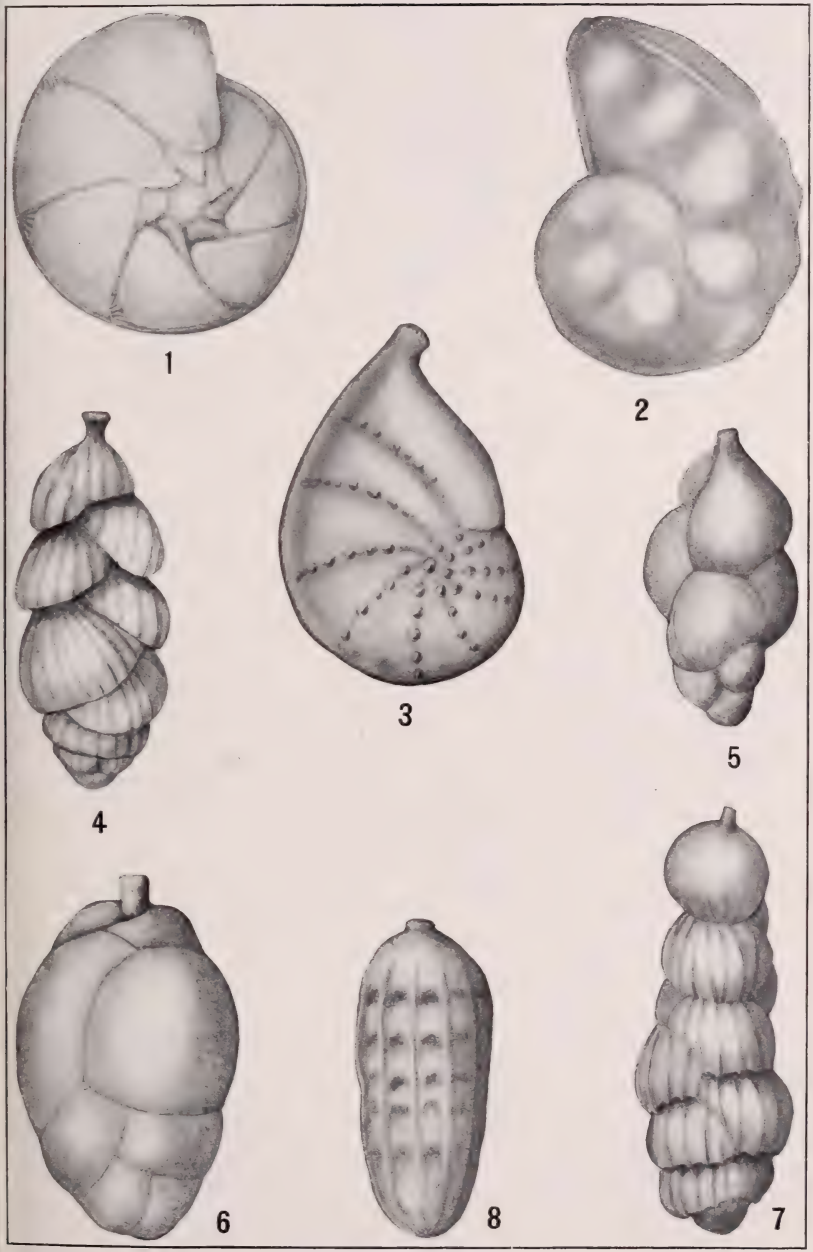

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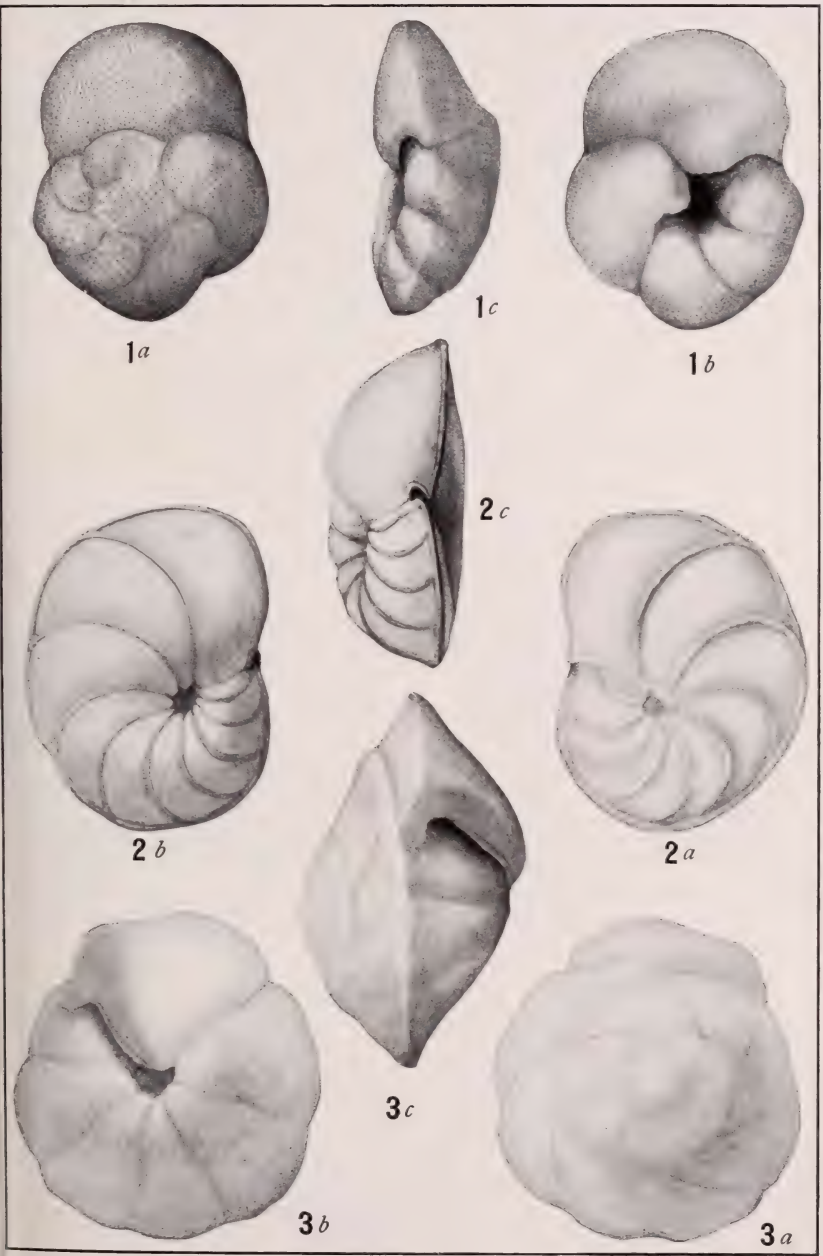

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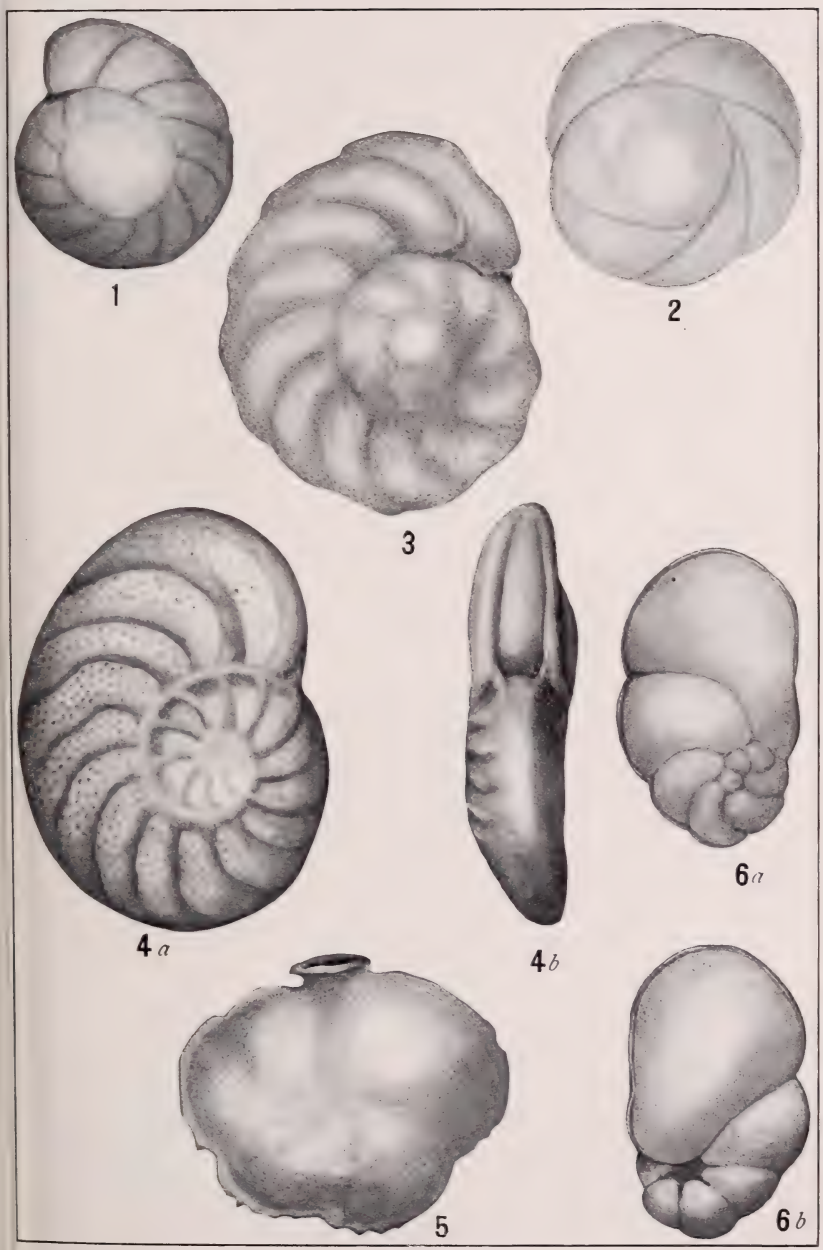

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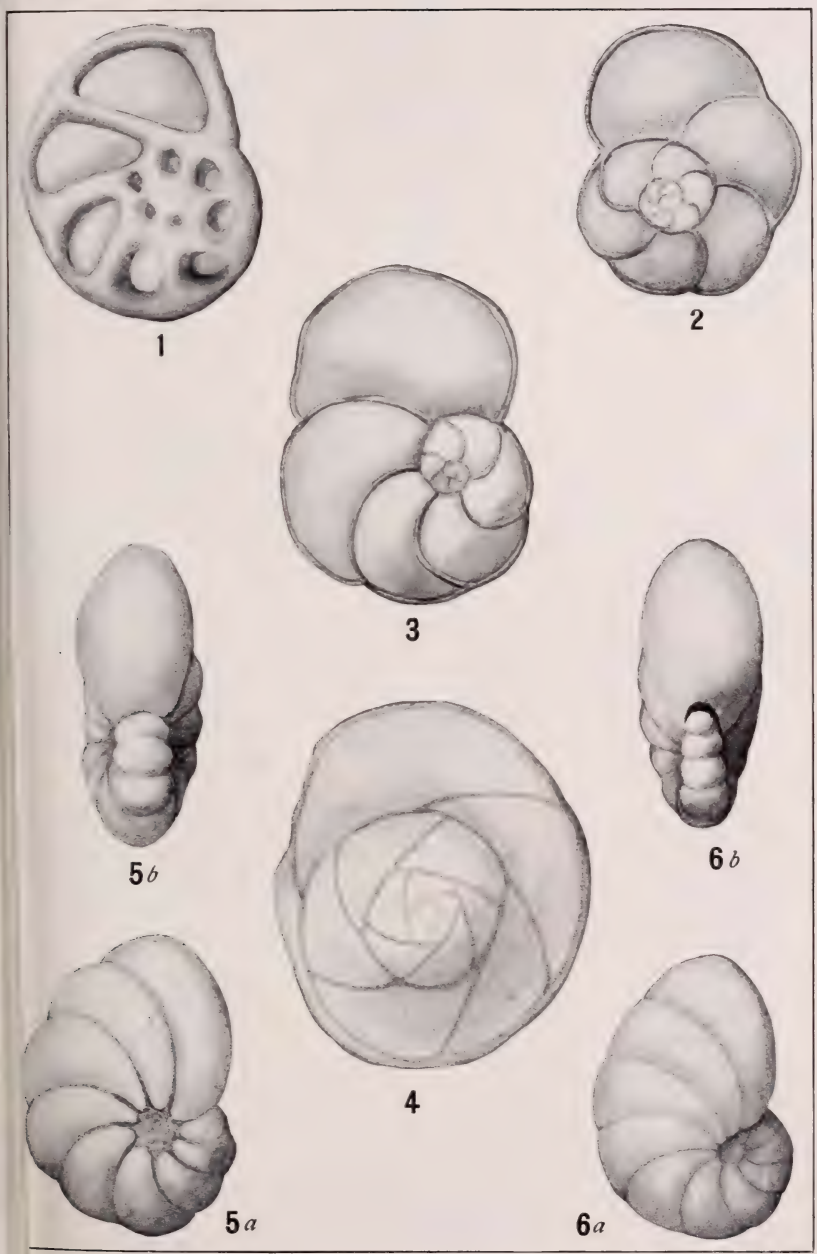

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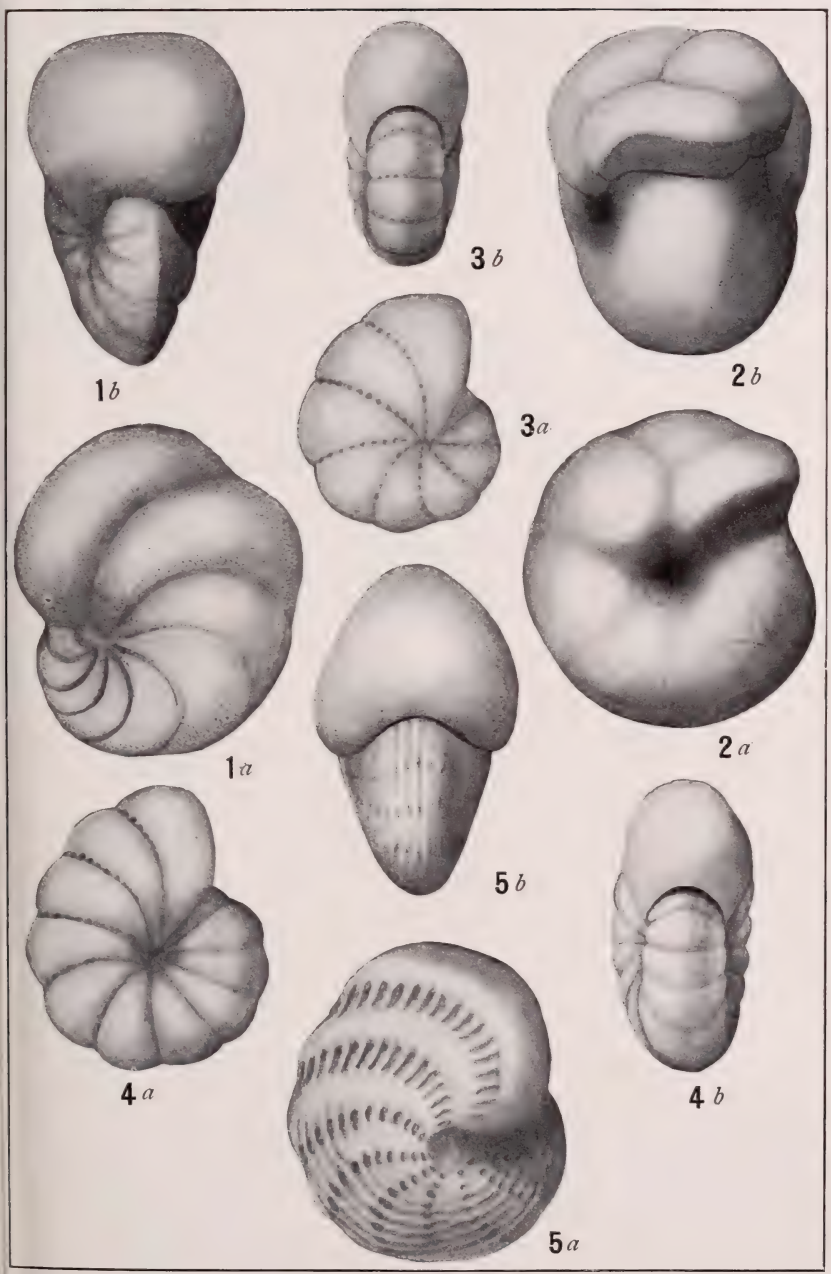

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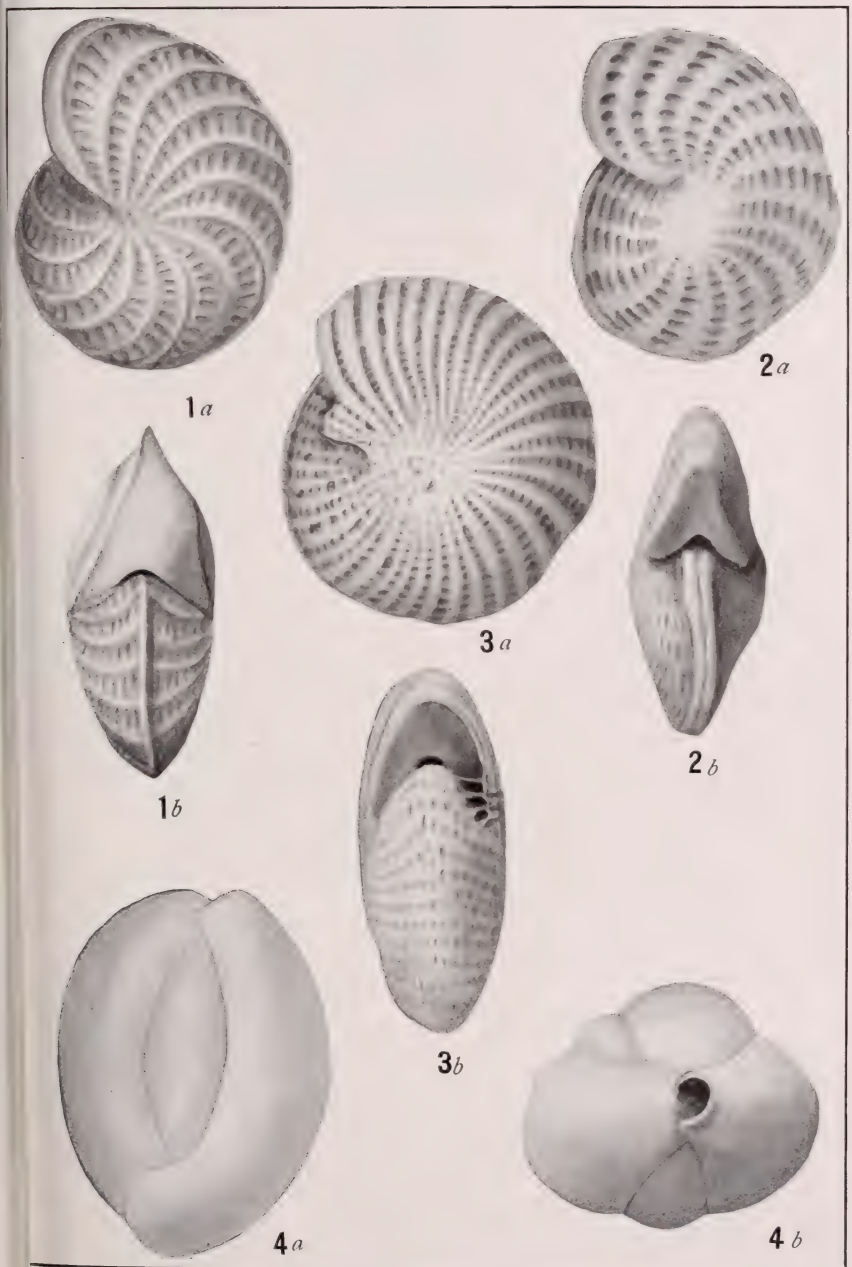

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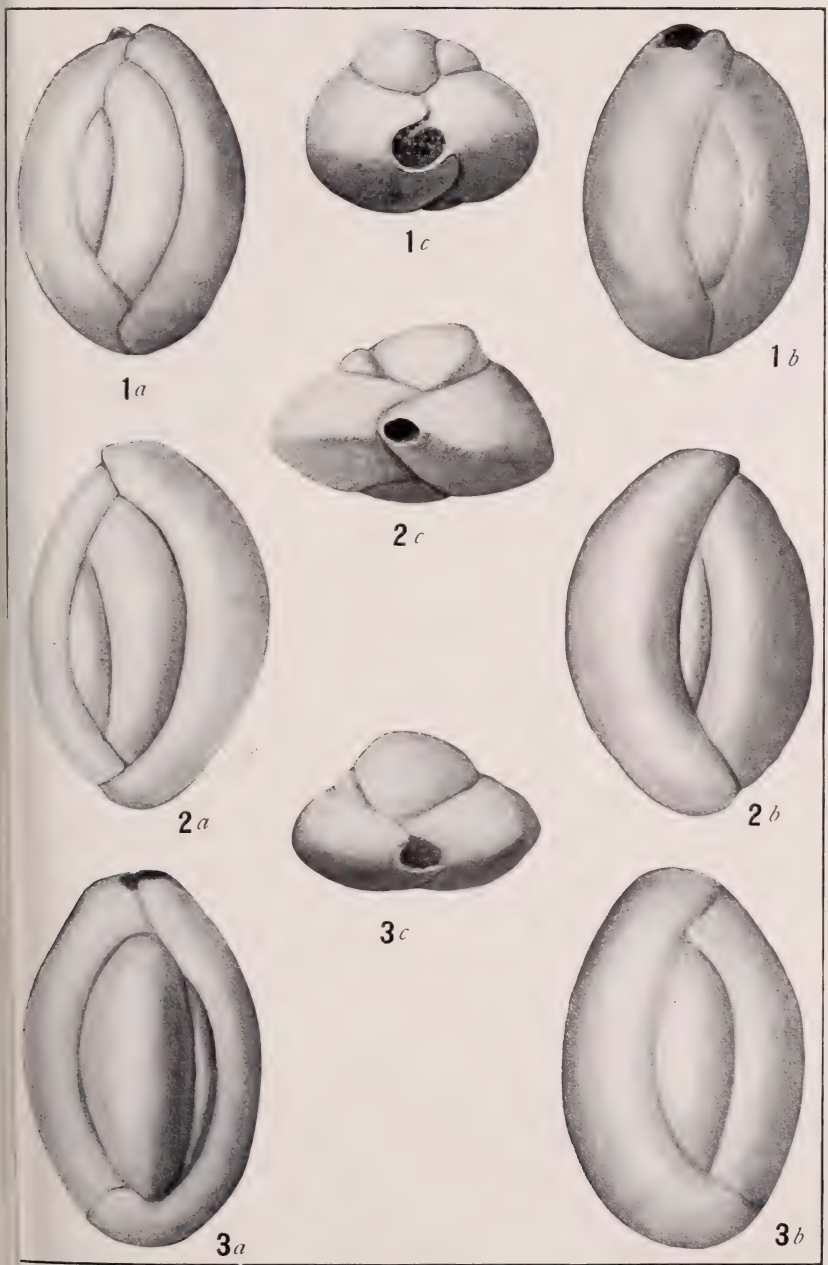

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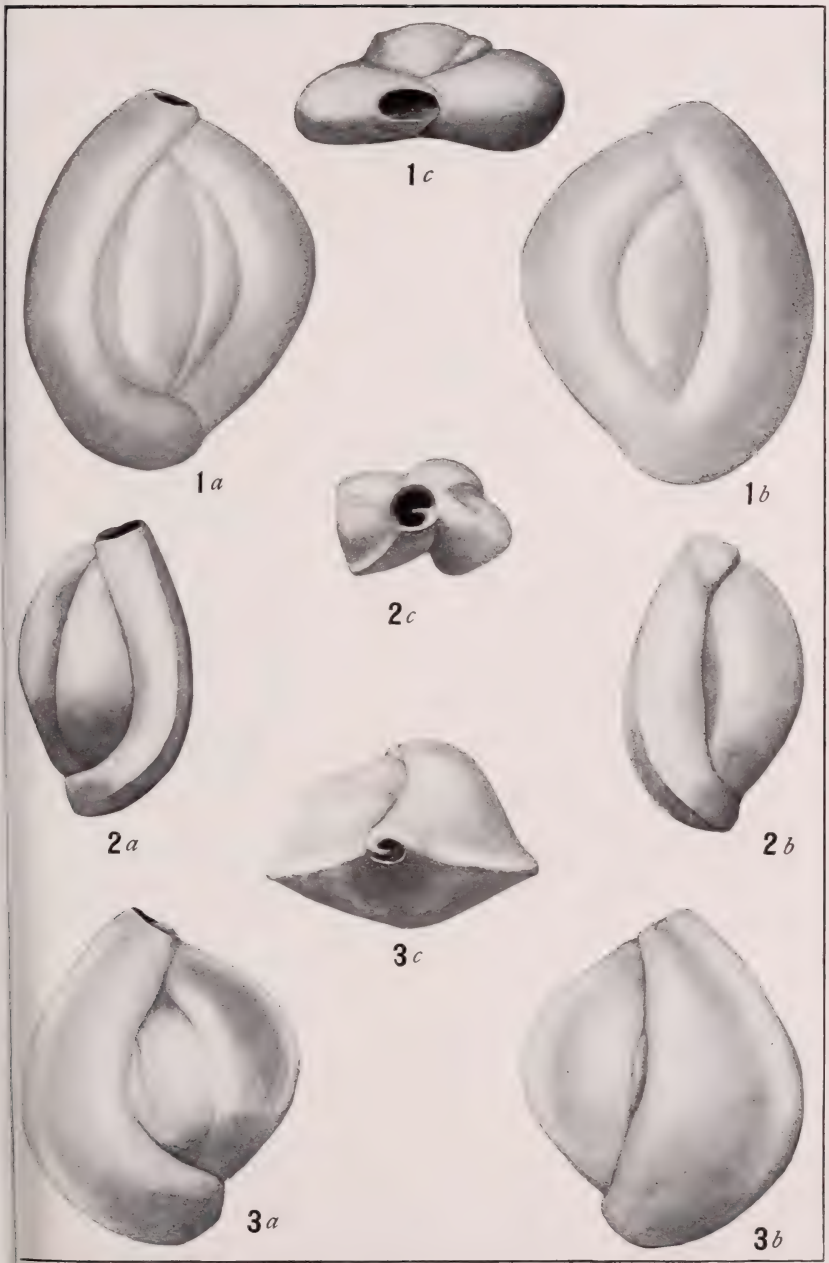

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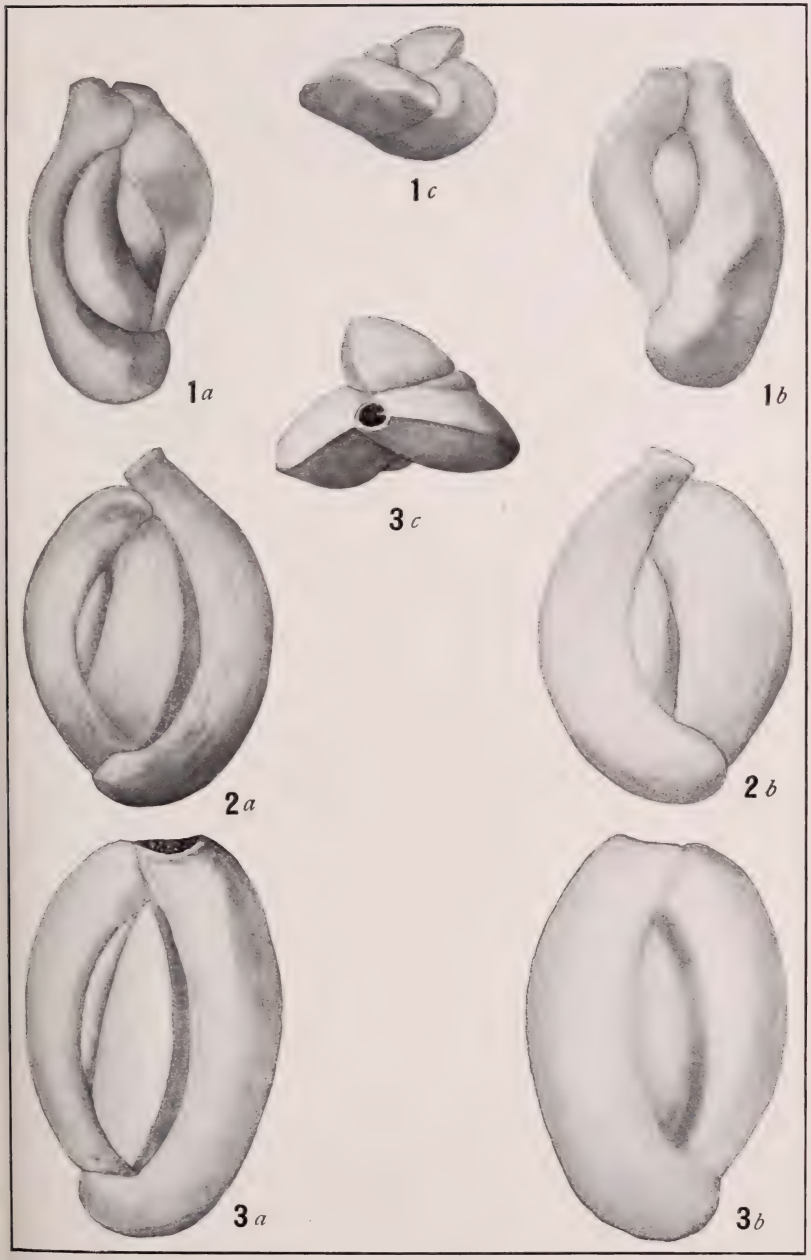

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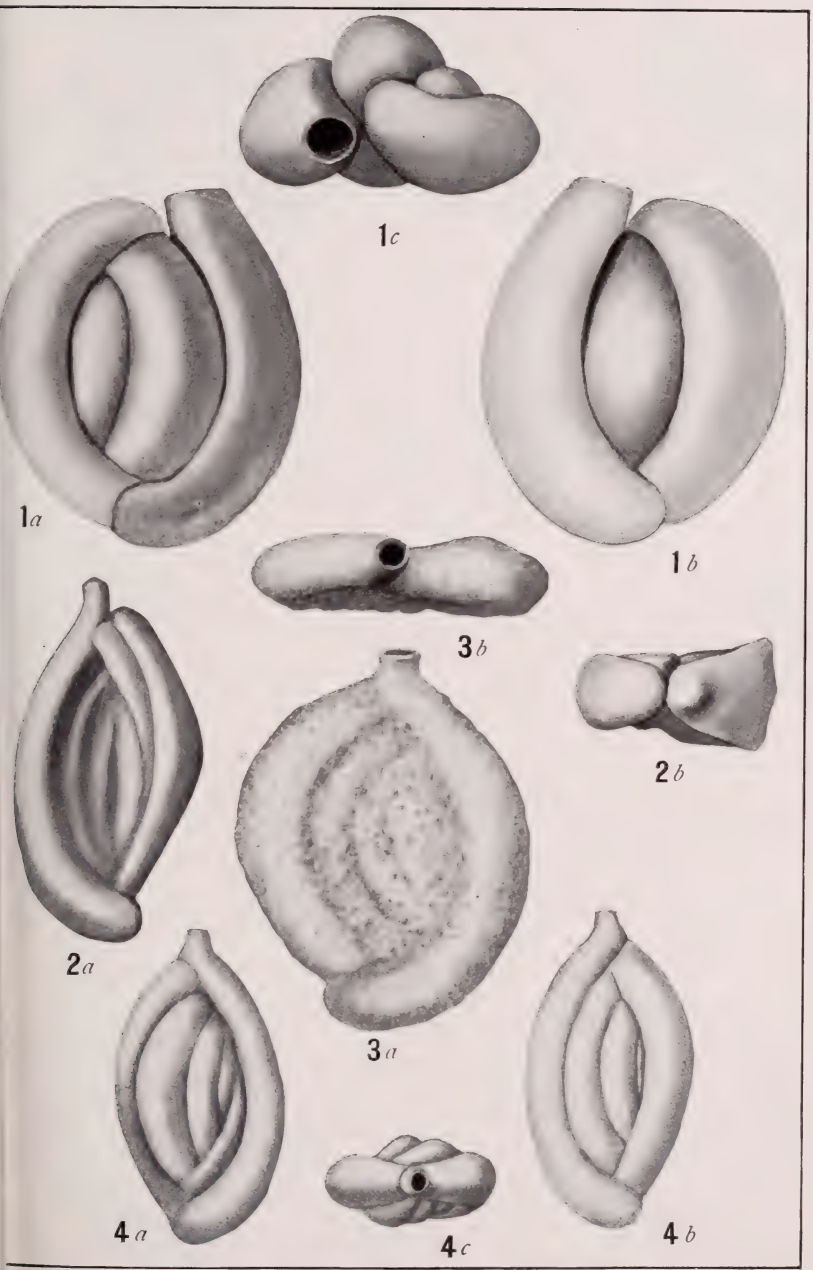

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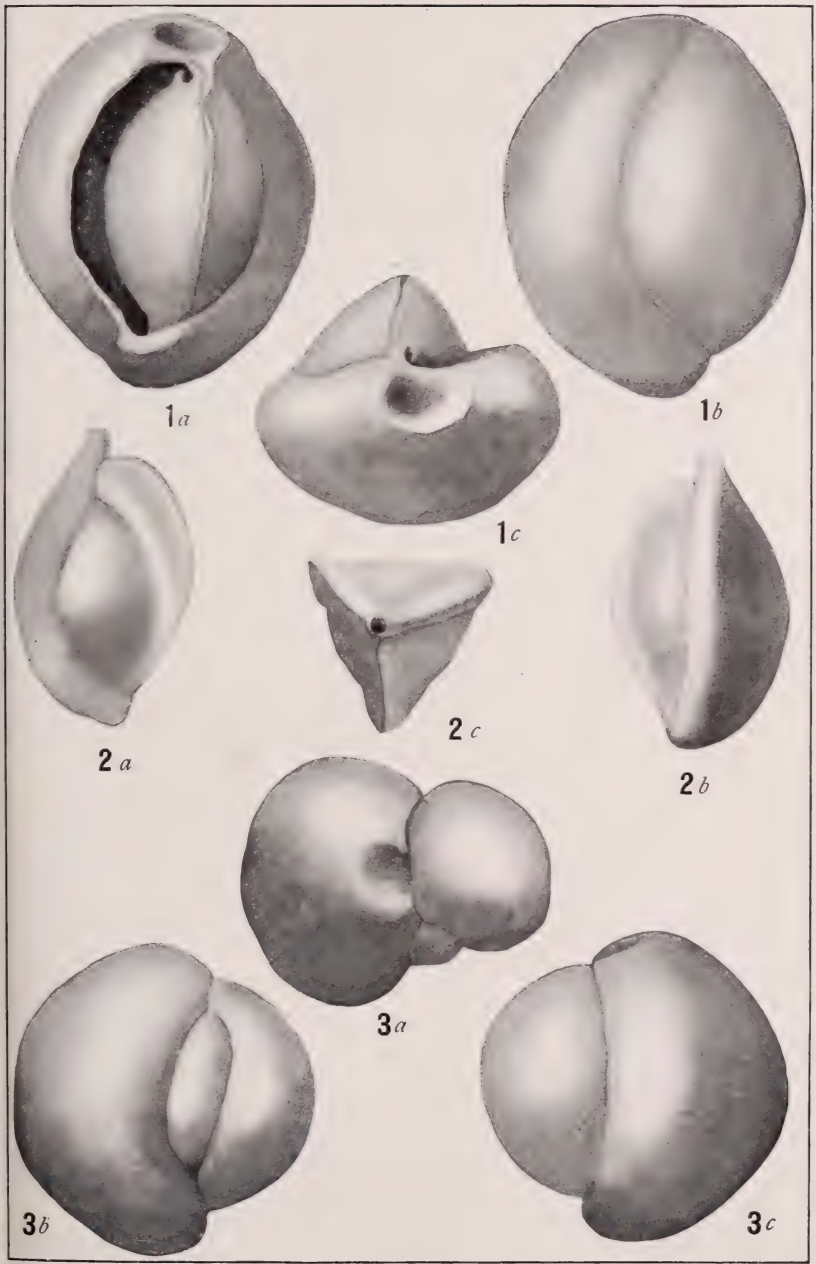

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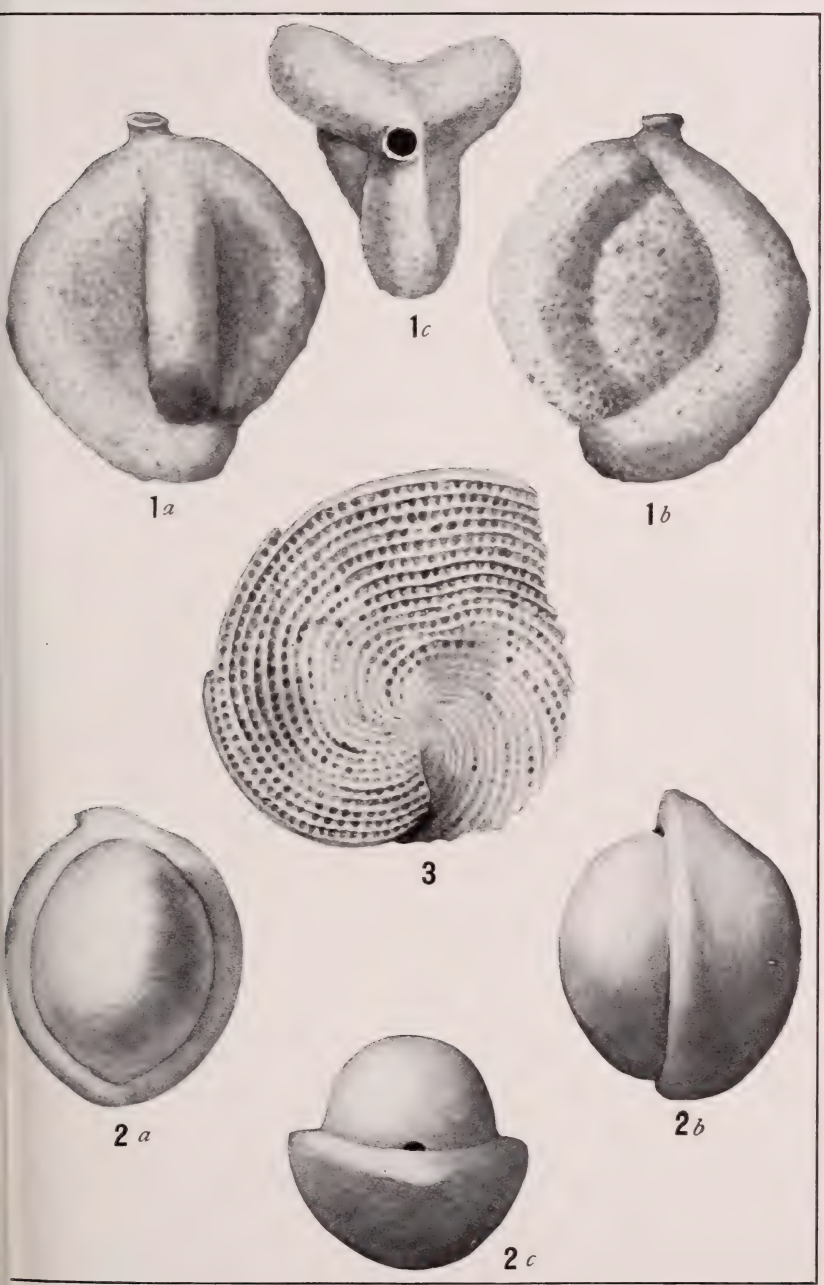

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vaughani, Cristellaria	
Virgulina	
squamosa	
wuellerstorfi, Truncatulina	

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

THE LARGER FOSSIL FORAMINIFERA OF THE PANAMA CANAL ZONE

By JOSEPH AUGUSTINE CUSHMAN
Of the United States Geological Survey

Extract from Bulletin 103, pages 89–102, with Plates 34–45

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1918

THE LARGER FOSSIL FORAMINIFERA OF THE PANAMA CANAL ZONE.

By Joseph Augustine Cushman,
Of the United States Geological Survey.

INTRODUCTION.

The foraminifera, especially the larger forms of the orbitoids, have been little used in America as critical index fossils, except in the Vicksburg group; but in Europe, Asia, and the East Indies they have long been used to distinguish horizons. In many geologic papers one finds *Orbitoides* mentioned, probably *Orbitoides mantelli* Morton, and occasionally *O. dispansus*, *O. forbesi*, etc. From a critical study of the group it soon becomes evident that such identifications as have been made of American orbitoids, except those of Lemoine and Douvillé, have been largely superficial, and are therefore of little value. Since the earlier work of Gümbel the orbitoid foraminifera have with further study been divided largely into the four genera *Orbitoides*, *Orthophragmina*, *Lepidocyclina*, and *Miogypsina*, in general respectively characterizing Cretaceous, Eocene, Oligocene, and Miocene formations, but with important exceptions. The American forms, with the exception of the work of Lemoine and Douvillé, have not been properly referred to their respective genera, although our American *Orbitoides mantelli*, described by Morton as *Nummulites mantelli* in 1833, is the type-species of *Lepidocyclina*. In their work on *Lepidocyclina* Lemoine and Douvillé[1] describe two new American species, *L. canellei* and *L. chaperi*, from the Panama Canal Zone, figuring also for the first time the critical chambers of *L. mantelli* (Morton). These are all the American species that are given, although they call attention to the apparently superficial character of the references to *Orbitoides* in American geologic papers. Schlumberger, in his classic works on the genera *Orbitoides* and *Orthophragmina*, did not have American material. The American

[1] Sur le Genre *Lepidocyclina* Gümbel, Mém. Soc. Géol. France, Paléontologie, Mem. 32, 1904.

field is therefore practically unworked, and the description of our species with accurate stratigraphic information is of prime importance, as they have been proved elsewhere to be of great use as index fossils.

The collections now in my hands represent the Canal Zone, the West Indies, and Coastal Plain Province of the eastern and southern United States. Excellent material was collected in the Panama Canal Zone by T. Wayland Vaughan and D. F. MacDonald, and is here presented as a beginning in the determination and figuring of the American species. This will be followed by papers on the West Indian and Coastal Plain species which now, owing to the careful collecting by Doctor Vaughan and his associates, are represented by excellent suites of specimens covering broad ranges, both geographically and stratigraphically. As these are gradually worked up there will be a mass of data which should be of excellent service in the correlation of horizons where these groups are represented, even in the absence of Mollusca and other groups of fossils.

The systematic descriptions of the species of *Lepidocyclina*, *Nummulites*, and *Orbitolites* follow, together with that of a genus and species believed to be new.

LIST OF SPECIES AND THEIR GEOLOGIC OCCURRENCE.

Lepidocyclina canellei Lemoine and Douvillé. Oligocene, Culebra formation, stations 6019*a*, Gaillard Cut; 6023, Rio Frijol; 6027, Bohio (old station); 6891; Bailamons; 6892, 450 feet south of switch at Mamei. Also Oligocene of Trinidad.

Lepidocyclina chaperi Lemoine and Douvillé. Oligocene, Culebra formation, stations 6019*f*, Las Cascadas; 6025, Bohio Ridge switch.

Lepidocyclina vaughani, new species. Oligocene, Emperador limestone, stations 6021 and 6673, near Caimito Junction; 6255, half mile south of Miraflores Station.

Lepidocyclina macdonaldi, new species. Oligocene, station 6523, miles north of David.

Lepidocyclina panamensis, new species. Oligocene?, stations 651 river bed, David; Oligocene, 6586*e* and 6587, near mouth Tonosi River; probably at 6010, near Miraflores Locks, a 6012*a* and 6012*e* in Gaillard Cut, in the Culebra formatio doubtfully in the Emperador limestone, at station 6015, Empi

Lepidocyclina duplicata, new species. Oligocene, stations 65 2 miles north of David; and 6586*e*, near mouth of Tonosi Riv

Heterosteginoides panamensis, new species. Oligocene, Culebra f mation, stations 6011, Gaillard Cut; 6024*a*, Rio Agua Salu 6025, Bohio Ridge switch. Emperador limestone, stations 60 6016, quarries at Empire.

Orthophragmina minima, new species. Oligocene ?, station 6512, river bed, David.

Nummulites panamensis, new species. Oligocene, Culebra formation, stations 6024*a*, Rio Agua Salud; 6025, Bohio Ridge switch; doubtfully at 6026, 2 miles south of Monte Lirio.

Nummulites davidensis, new species. Oligocene?, stations 6512, river bed, David; 6526, Chiriqui.

Orbitolites americana, new species. Oligocene, Culebra formation, Gaillard Cut at stations 6013, 6019*b*, and 6020*a*.

DESCRIPTIONS OF SPECIES.

Family NUMMULITIDAE.

Genus LEPIDOCYCLINA.

LEPIDOCYCLINA CANELLEI Lemoine and Douvillé.

Plate 34, figs. 1–6.

Lepidocyclina canellei LEMOINE and DOUVILLÉ. Mém. Soc. Géol. France, Paléontologie. Mém. 32, p. 20, pl. 1, fig. 1; pl. 3, fig. 5, 1904.

Test comparatively small, diameter of largest specimens slightly ess than four millimeters, thickness a little more than one-fourth the iameter; circular in outline, central portion somewhat raised and venly rounded, near the periphery flattened or even slightly conave; surface in well preserved specimens finely granular or even nely papillate, but not strongly so, often appearing smooth to the naided eye. In worn specimens the surface appears as a series of egular hexagonal, honeycomb-like reticulations due to the edges f the lateral chambers.

In vertical section the lateral chambers are seen to be arranged in ertical columns, one directly above the other, from the equatorial hambers to the surface, about twelve chambers in each vertical colmn in the central region, the lateral walls hardly thicker than the pper or lower surfaces. Chambers of adjacent columns arranged ternately, no distinct columns present. Equatorial chambers gradally increasing in size toward the periphery, single throughout, exnding peripherally beyond the lateral chambers and in surface view well-preserved specimens appearing as a hexagonal reticulation. mbryonic chambers nearly equal in size, nearly semicircular in secon, their common wall straight.

Horizontal section showing the equatorial chambers regularly xagonal, those toward the periphery largest. Embryonic chamrs similar to those shown in the vertical view.

Occurrence.—Lemoine and Douvillé described and figured this ecies from Panama, from Peñablanca, also noting it from Mar-

tinique and Angola. The species from Panama was recorded by Dall and by Bagg as *Orbitoides forbesi* Carpenter.[1]

Cat. No. 135216, U.S.N.M., is *Lepidocyclina canellei* Lemoine and Douvillé. Figures 1, 4–6, on plate 34 are from this material, collected by Hill at Bohio, Panama, where it is very abundant. This is the same locality as station 6027 of Vaughan and MacDonald, orbitoidal marl, a quarter of a mile northwest of Bohio railroad station. In this material *L. canellei* is very abundant and makes up a considerable proportion of the marl. Parts of five specimens, close to one another, are visible in a small part of a section from this station.

Specimens in the collection of the United States National Museum, Catalogue No. 107158, from the Oligocene of Trinidad ("Leda bed," Naparima) collected by Guppy, are also very evidently *Lepidocyclina canellei.*

Specimens of *L. canellei* were also very abundant at station 6891 foraminiferal limestone from Bailamonas, Canal Zone, collected by D. F. MacDonald.

There is a limestone from station 6892, 450 feet south of switch at Mamei, Canal Zone, also collected by MacDonald, which contains numerous specimens of a Lepidocyclina in general shape in section resembling *L. canellei*, but the material is very cherty and the fine structure is not well preserved.

A few small weathered specimens from 6019*a*, Gaillard Cut, opposite Las Cascadas, seem to belong to this species also; and specimens were also obtained at station 6023, along the relocated line of the Panama Railroad, at Rio Frijol. The geologic occurrence is in the Culebra formation.

Cat. Nos. 324733–5, U.S.N.M.

LEPIDOCYCLINA CHAPERI Lemoine and Douvillé.

Plate 35, figs. 1–3; plate 36.

Lepidocyclina chaperi Lemoine and Douvillé, Mém. Soc. Géol. France, Paléontologie, Mém. 32, p. 14, pl. 2, fig. 5, 1904.

Test of medium size, diameter from 8 to 20 millimeters, circular in outline, somewhat saddle-shaped, central portion slightly thickened, thence gradually and evenly thinning toward the periphery; surface where well preserved slightly papillate, usually roughened by erosion, toward the periphery often somewhat reticulately depressed above the equatorial chambers.

Vertical section usually curved, lateral chambers numerous, breadth much greater than height, columns separated by distinct pillars, comparatively few except in the central region where the

[1] Hill, Geology of Panama, Bull. Mus. Comp. Zöol., vol. 28, pp. 272, 275, 1897.

re a few larger than the others; embryonic chambers of the double ype, the two chambers nearly equal in size and separated by a traight common wall.

Horizontal section shows similar conditions of the embryonic hambers and distinctly hexagonal equatorial chambers.

Occurrence.—Lemoine and Douvillé described this species from 'anama (Haut-chagres, San Juan). The figured specimens are from Inited States Geological Survey station 6025, Culebra formation, rom marl, south end of Bohio Ridge switch, relocated line, Panama ailroad, collected by Vaughan and MacDonald.

Specimens from station 6019–*f*, Culebra formation, on the west de of Gaillard Cut near Las Cascadas, seem to represent the micro-pheric form of this species. The sections are shown in plate 35, gure 3, and plate 36.

A specimen from station 6526, Chiriqui, Canal Zone, shows a sec on which from its general proportions strongly suggests *L. chaperi*. Cat. Nos. 324736–8, U.S.N.M.

LEPIDOCYCLINA VAUGHANI, new species.

Plate 37, figs. 1–5; plate 38.

Test of medium size, 10 millimeters or more in diameter, flat, sur-ce somewhat umbonate in the central portion, gradually sloping to ie peripheral portion, the outer half of which is nearly flat. Wall nooth except for fine papillae.

Horizontal section shows the peculiarity of the chambers, many of hich, especially those of the outer peripheral portion are rhomboid, ose of the inner portion being more typical and hexagonal. These e shown especially well on the sections of the larger specimens, ose of the smaller specimens showing only the regular hexagonal aracter of the earlier chambers.

No very good vertical sections were obtained in the thin sections it several accidental sections show the characters well. The em-yonic chambers are rather large, of the usual American type, of o nearly equal chambers, lateral chambers in vertical columns ith a very few, rather well developed pillars.

Occurrence.—Type-specimen from station 6021, from the Empera-r Limestone in cuttings of the Panama Railroad near Caimito unction, Panama, United States National Museum Catalogue No. 4739, collected by T. W. Vaughan and D. F. Mac Donald. Speci-ens were abundant in this light gray to cream-colored sandy lime-one. Specimens were also abundant in the collection from the same ality collected later by MacDonald under station No. 6673. Speci-ens which are apparently the same species are abundant in a fos-

siliferous limy sandstone collected by MacDonald at station No. 6255 from half a mile south of Miraflores Station on the wagon road to Panama.

LEPIDOCYCLINA MACDONALDI, new species.

Plate 40, figs. 1–6.

Test circular, rather small, about 5 to 7 millimeters in diameter, thickest in the central region, thence gradually sloping to the periphery which for a short distance in from the edge is nearly flat; wall rather smooth except the central portion of the umbonal region which has a few pustule-like raised spots at the surface end of the vertical pillars.

Vertical section shows the test widest in the middle, gently sloping to near the periphery where the edges are nearly parallel for a short distance to the peripheral edge or even slightly increasing in thickness. Lateral chambers in the central portion in definite vertical columns, occasionally slightly overlapping. Equatorial chambers not increasing very rapidly in height in megalospheric specimens, those at the periphery hardly more than double the height of those near the center of the test; embryonic chambers in the megalospheric form, large, usually of two nearly equal chambers, but in oblique cutting these may appear somewhat unequal, plate 40, figures 2 and 3.

Horizontal sections show chambers somewhat similar to *L. vaughani* but with the inner half of two walls at nearly right angles, the outer wall broadly rounded. The oblique section (pl. 40, fig. 6) shows the pillars.

Occurrence.—Type-specimens from station 6523, from orbitoid limestone, 2 miles north of David, Panama, collected by D. F. MacDonald, U. S. National Museum Catalogue No. 324740. Specimens were abundant at this station, occurring with *L. panamensis* and *L. duplicata*. The species were also collected by MacDonald at station 6512, in the river bed at David.

LEPIDOCYCLINA PANAMENSIS, new species.

Plate 39, figs. 1–6; plate 42.

Test circular, small, central portion very strongly umbonate, thickness rapidly decreasing in thickness peripherally, the peripheral portion thin and flattened, the raised central portion only one-third to one-fifth the entire diameter, which ranges from three to six millimeters; occasional specimens, perhaps representing the microspheric form, up to 10 or 12 millimeters in diameter; surface smooth except for the unbonal portion which has a few large pustule-like projections marking the ends of the internal pillars.

The vertical section shows very peculiar embryonic chambers in hat they do not exhibit the usual characters of American species, but ave a broad and much flattened central chamber two to four times s broad as high with a compressed, partially encircling chamber, hich in section is usually cut on the opposite sides of the central hamber. In some cases there seems to be an irregular mass of three r four more or less nearly spherical chambers. In the former case ese central chambers in section are nearly as wide as the whole mbonal portion of the test. Lateral chambers, usually about twice s wide as high, the outer wall often somewhat arched toward the xterior of the test, arranged in vertical columns. Pillars not dis-nct except in the central portion where there are a few strong ones ncreasing rather rapidly in diameter toward the periphery, usually out 9 or 10 chambers in a vertical column in the center of the nbilical region. The peripheral region has only a thin coating of teral chambers, the last formed layer present only on the outer lf of the periphery and often none at all present on the last quar-r of the test toward the periphery, the surface being made up by per and lower walls of the equatorial chambers. Equatorial cham-rs numerous, comparatively broad, the peripheral wall convex out-ardly toward the periphery, the chambers at least as wide as high.

In horizontal section the equatorial chambers are usually some-hat irregularly hexagonal near the center, toward the periphery ore or less rhomboid with the outer peripheral wall curved.

As far as described material is concerned this is an unusual form r American species of *Lepidocyclina*, especially in its embryonic ambers.

Occurrence.—Type-specimen, vertical sections, U. S. National luseum Catalogue No. 324741. The species is fairly abundant at tions 6586*c* and 6587 from near the mouth of Tonosi River, nama, D. F. MacDonald, collector. It was also collected by Mac-nald at station 6512, river bed, David.

At stations 6010, 600 or 700 feet south of the Miraflores Locks, and 012*a* and 6012*c*, south of Empire Bridge, in the Culebra formation, ecimens of small orbitoids occur, but they are not sufficiently well eserved for positive identification. Although those from the latter tion seem somewhat like *L. panamaensis* in their thin borders d raised center with papillae, they can not be specifically identified h certainty. At other stations poorly preserved orbitoid fo-minifera occur, but their specific identity can not be accurately ermined. Specimens doubtfully referable to *L. panamensis* were ained in the Emperador limestone, at station 6015, Empire.

MULTICYCLINA, new subgenus.

Subgenus differing from typical *Lepidocyclina* in the equatori chambers which instead of being in a single series become compl toward the periphery and may consist of several series.

Type of the subgenus.—*Lepidocyclina duplicata* Cushman.

LEPIDOCYLINA DUPLICATA, new species.

Plate 41, figs. 2–4.

Test of medium size, 10 to 14 millimeters in diameter, very m thickened in the umbonal region, usually the thickness about one-h the diameter; without the flattened periphery the central port is subspherical, thinning rapidly toward the periphery, then thi- ening again at the margin, which is often doubly plicate in the l preserved specimens. Surface of the umbonal portion studded w numerous fine papillae marking the surface terminations of the l- lars, peripheral portion nearly smooth.

Vertical section showing the embryonic chambers as very sm l, apparently microspheric in the specimens sectioned, appearing spa as is usual in the microspheric form. Lateral chambers numer s, flattened or lenticular, the numerous pillars as wide as or wider t n the intermediate columns of chambers, especially in the central r- tion, rapidly increasing in size toward the surface. Equat al chambers very small near the center, gradually increasing in ze toward the periphery where they become multiple instead of si le as is usually the case, and make three or four vertical series, ch with numerous fine apertural pores on the outer convex wall.

Horizontal section shows the increase in size of the equat ial chambers which toward the center seem hexagonal and toward he periphery almost rhomboid with the outer half convex.

Of somewhat similar character as far as the duplication of e a- toral chambers is the species described by Martin from Jav *L. multipartita* (Martin), and the form described by Jones and P ker from Christmas Island, *L. insulae natalis*, var. *inequalis* (Jones nd Parker).

Occurrence.—Type-specimen, U. S. National Museum, Cata gue No. 324742. Specimens were very abundant, weathered out of a or- bitoid limestone, at Station 6523, 2 miles north of David, Pa ma, D. F. MacDonald, collector. They also occur with other spec s of *Lepidocyclina* at Station 6586*e* from near the mouth of Tonosi I ver, D. F. MacDonald, collector.

HETEROSTEGINOIDES, new genus.

Test generally lenticular, somewhat excentric, one side extended ripherally more than the other, chambers rather coarsely perrate, embryonic chambers, often two, of nearly equal size, thick lled, chambers added as in *Heterostegina*, in a revolving series exding from the umbonal region on both sides to the periphery, ambers hemispherical, the outer side strongly convex and all arsely perforate, the equatorial chambers larger than the lateral es and nearly spherical.

Type of the genus.—*Heterosteginoides panamensis*, new species.

HETEROSTEGINOIDES PANAMENSIS, new species.

Plate 43, figs. 1–8.

Test biconvex, somewhat more strongly convex on one side than on e other, revolving edge indistinct, surface unevenly rugose, or irgularly pustulate, thickest in the umbonal region. Vertical section owing the embryonic chambers as an equal pair of nearly spherical, ick-walled chambers, equatorial chambers also nearly spherical, teral chambers hemispherical with the curved side outermost, irgularly piled above the equatorial chambers. Horizontal section owing the central chambers with the equatorial chambers arranged an irregular semi-spiral manner about them.

Test small, between 1 and 2 millimeters in diameter. Cat. Nos. 24743–4, U.S.N.M.

Occurrence.—This species was abundant in the Culebra formation t station 6025, from marl, south end of Bohio Ridge switch, relocated line, Panama Railroad, collected by Vaughan and MacDonald. There are also numerous specimens at station 6011, Culebra formaon, along east side of Gaillard Cut, collected by Vaughan and MacDonald. It was also collected in the Culebra formation at station 024–*a*, Rio Agua Salud, and is doubtfully present in the Emperador mestone at stations 6015 and 6016, in Empire.

This species, which in external appearance somewhat resembles a mall orbitoid or nummulite, may be distinguished from most species f either group by its comparatively coarse pustulate exterior. In ection it can easily be recognized by its peculiar structure.

Genus ORTHOPHRAGMINA.

ORTHOPHRAGMINA MINIMA, new species.

Plate 41, fig. 1.

Test circular, very small, slightly more than 2 millimeters in liameter, thickness somewhat less than half the diameter, central portion very strongly umbonate, evenly rounded to a point about

two-thirds of the distance from the center to the periphery, fr
which point to the periphery the surface is nearly flat; surface
the test comparatively smooth.

Horizontal section through the equatorial chambers shows v
fine rectangular chambers and the embryonic chambers nearly eq
in size.

Vertical section (fig. 1) shows well the contour of the test in t
section, the strongly curved central umbonate portion making
two-thirds or more of the width and the peripheral flange with
nearly parallel sides. The chambers are very small, except
embryonic central chambers, which are nearly equal and hav
straight division line between them. The lateral chambers are
vertical columns, but the test is without pillars. In the central reg
there may be more than 20 chambers in a vertical column, and e
on the peripheral flange there are usually three or four in a colu
on each side of the equatorial chambers.

Occurrence.—Type-specimen—the vertical section here figur
Collection of the U. S. National Museum Catalogue No. 324745.

The species is abundant at United States Geological Survey
tion 6512 in the white limestone, in the river bed above the ice pl
near David, Panama, collected by D. F. MacDonald.

This is a very small species yet it has an abundance of very
chambers. There is an exceptional development of lateral chamb
in the region of the periphery.

Genus NUMMULITES.

NUMMULITES PANAMENSIS, new species.

Plate 43, figs. 9, 10.

Test small, about 1½ millimeters in diameter, much compres
chambers very numerous, about 22 in the last formed coil, each
section two to three times as high as long, test of about four whor
walls comparatively thick, whole test lenticular, peripheral mar
broadly rounded, central portion nearly flat.

Occurrence.—Specimens occur with some frequency in the Culebra
formation at station 6025, in marl, south end of Bohio Ridge swi
relocated line, Panama Railroad, collected by Vaughan and Mc-
Donald. Type-specimen, U. S. National Museum Catalogue
324746. The species was also collected in the Culebra formatio
station 6024–*a*, Rio Agua Salud, and doubtfully at station 602
miles south of Monte Lirio, on the relocated line of the Pan
Railroad.

NUMMULITES DAVIDENSIS, new species.

Plate 43, fig. 11.

Test comparatively small, about 3½ millimeters in diameter, so
what compressed, chambers about twice as high as long in me

ions, test of three or four whorls, walls of medium thickness, upright wall rather strongly recurved backward in the central tion, 15 or 16 chambers in the last formed whorl.

ccurrence.—Specimens were not common at station 6512 from te limestone in river bed above ice plant near David, Panama, ected by D. F. MacDonald.

ype-specimen.—Cat. No. 324751, U.S.N.M.

n material from station 6526 from Chiriqui, Canal Zone, col- ed by MacDonald, numerous specimens occur which in section n identical with this species.

Family MILIOLIDAE.

Genus ORBITOLITES.

ORBITOLITES AMERICANA, new species.

Plate 43, figs. 12–14; plate 44, figs. 1, 2; plate 45.

est flat, of medium size, larger specimens about 10 millimeters liameter, chambers with the outer wall strongly convex, the inner l running backward and bluntly pointed, side walls parallel, mbers in two or more tiers; tests mostly microspheric, one (pl. 43, 14) apparently megalospheric, and one (pl. 44, fig. 2) seemingly ginating from a fragment of an older test. Numerous specimens, ecially plate 45, figure 1, show evidence of breakage and repair. e apertures between the chambers are not evident, as the material ely consists of internal casts of the chambers. Some of the cimens suggest the genus *Presorites* of the Cretaceous described Douvillé, but this is probably due to the condition of fossilization.

ccurrence.—Specimens which seem referable to this species are m the following stations at Panama, collected by Vaughan and cDonald: Culebra formation, 6013, east side of Gaillard Cut; 9*b*, 6019–*e–f*, west side of Gaillard Cut near Las Cascadas; and 0*a–c* of the same section. Also collected in the Emperador lime- ne at station 6015, in Empire.

ype-specimen.—Cat. No. 324748, U.S.N.M., from station 6020*a*.

EXPLANATION OF PLATES.

PLATE 34.

Lepidocyclina canellei Lemoine and Douvillé.

1. View of exterior of specimen × 10, a portion of a second specimen showing above the first, from Bohio, Panama. (U.S.N.M. Cat. No. 135216.)

2. Horizontal section × 10, showing embryonic chambers and hexag equatorial chambers, from west side of Gaillard Cut near Las cadas (U.S.G.S. station 6019*a*).
3. Horizontal section showing hexagonal equatorial chambers and irr larities in the annuli due to repairs of breakage. *a* × 10; *b* × Same locality as No. 2 above.
4. Slightly oblique section × 20, showing narrow zone of equatorial cl bers and two broader zones of lateral chambers, the latter with a evident lack of pillars. Same locality as No. 1 above.
5. Vertical section at one side of embryonic chambers showing gen characters of equatorial and lateral chambers × 20. Same loc as No. 1 above.
6. Vertical section through the embryonic chambers showing the nearly equal chambers with the straight wall dividing the two, × Same locality as No. 1 above.

PLATE 35.

Lepidocyclina chaperi Lemoine and Douvillé.

FIG. 1. Exterior view of specimen × 5. Specimen broken. From upper of Culebra formation, from Panama Railroad, southern switch, Ridge, in light-colored limy sandstone (U.S.G.S. station 6025).
2. Exterior view of small, more complete specimen from same localit the preceding, × 5.
3. Horizontal section showing early chambers of the microspheric for the species, × 20. From west side of Gaillard Cut near Las Cas (U.S.G.S. station 6019*f*).

PLATE 36.

Lepidocyclina chaperi Lemoine and Douvillé.

Horizontal section × 10, showing early central chambers and hexa chambers of the equatorial region (U.S.G.S. station 6019*f*).

PLATE 37.

Lepidocyclina vaughani, new species.

FIG. 1. View of exterior of specimen × 5. with flat periphery and umb center, from limy sandstone half a mile south of Miraflores St on wagon road to Panama (station 6255).
2. Horizontal section of young specimen with regularly hexagonal torial chambers × 20 (same locality as No. 1).
3. Oblique section × 20, with narrow zone of regularly hexagonal torial chambers and broader zones of lateral chambers and a st division wall (same locality as No. 1).
4. Specimen showing zone of equatorial chambers about periphera tion, lateral chambers covering them in the center × 10. From stone in cut of relocated line of Panama Railroad opposite San and about 4 miles north of Gamboa bridge (station 6673).
5. Portion of vertical section (slightly oblique) through the emb chambers, × 20 (same locality as No. 1).

PLATE 38.

Lepidocyclina vaughani, new species.

ecimen × 20, showing peripheral zone cut through the equatorial chambers
central portion covered by lateral chambers. From limestone in cut of re-
ed line of Panama Railroad opposite San Pablo and about 4 miles north
amboa bridge (station 6673).

PLATE 39.

Lepidocyclina panamensis, new species.

1. Very young specimen in vertical section consisting of embryonic chambers and one or two following chambers, × 20.

2–4. Vertical sections with broad embryonic chambers and showing the relation of equatorial and lateral chambers, vertical columns of lateral chambers with intermediate pillars, × 20.

5. Oblique section with zone of hexagonal equatorial chambers, × 20.

6. Section of rock with six specimens lying closely adjacent, four of these cut through the embryonic chambers, × 20.

l specimens from near the mouth of Tonosi River, Panama (station
e).

PLATE 40.

Lepidocyclina macdonaldi, new species.

1. Exterior view of specimen, × 10, showing pillars appearing at the surface as raised area.

2–5. Vertical sections (slightly oblique) through the embryonic chambers, which when cut in plane at right angles to division wall show nearly equal chambers with the division wall straight or very slightly curved. Pillars evident, especially in Nos. 2 and 5. × 20.

6. Oblique section, × 20, showing zone of "lozenge-shaped" equatorial chambers with lateral chambers on each side. The upper series showing the cut sections of pillars.

ll specimens from limestone 2 miles north of David, Panama (station 6523).

PLATE 41.

Orthophragmina minima, new species.

1. Vertical section, × 20, showing general outline and numerous very fine chambers. From white limestone in river bed above ice plant, David, Panama (U.S.G.S. station 6512).

Lepidocyclina duplicata, new species.

2. Exterior view of type, × 5, showing raised center and depressed area inside the raised periphery.

3. Portions of vertical section showing great increase in width of equatorial zone, multiplication of chambers toward the periphery, heavy pillars and wide lateral chambers. × 20.

4. Portion of oblique section showing narrow zone of "lozenge-sha equatorial chambers, perforations of peripheral wall of outer torial chambers and perforated pillars among the lateral chan × 20.

All specimens of *L. duplicata* from limestone, 2 miles north of David, Pa (station 6523).

PLATE 42.

Section of limestone from station 6523, 2 miles north of David, showin merous specimens of *Lepidocyclina*, × 20. Left center, *L. panamensis* broad embryonic chambers; lower middle *L. macdonaldi* with subspherica bryonic chambers; at right a portion of *L. duplicata*.

PLATE 43.

Heterosteginoides panamensis, new genus and new species.

FIG. 1, 2. External view of specimens, × 10, from limy sandstone, east si Gaillard Cut (station 6011).

3–6. Vertical portions, × 20, showing irregular piling of lateral cham fig. 6 with two embryonic chambers with thick walls. Speci from limy sandstone near southern switch, Bohio Ridge (st 6025).

7, 8. Horizontal sections, × 20, from same locality at Bohio.

Nummulites panamensis, new species.

9. Horizontal section, × 20, from limy sandstone near southern sw Bohio Ridge (station 6025).

10. Vertical section from same rock specimen, × 10.

Nummulites davidensis, new species.

11. Horizontal section, × 20, from white limestone in river bed abo plant, David, Panama (station 6512).

Orbitolites americana, new species.

12–14. Horizontal sections, × 10, specimens from west side of Gaillard near Las Cascadas (station 6020*a*).

PLATE 44.

Orbitolites americana, new species.

FIG. 1. Horizontal section of large specimen, × 10, from Gaillard Cut, nea Cascadas (station 6019–*b*).

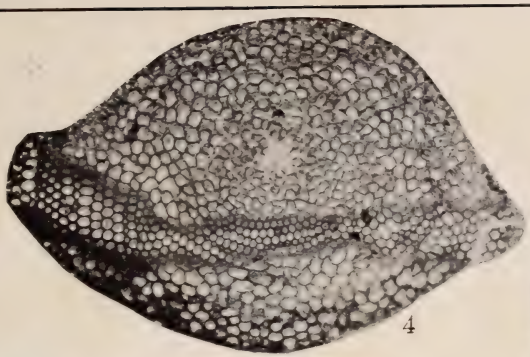
2. Horizontal section, broken, showing two layers of chambers and i cast of outer surface, × 20 (station 6020*a*).

PLATE 45.

Orbitolites americana, new species.

Specimen in horizontal section, × 20, showing several areas of breakag subsequent repair, shown by the angular reëntrants of the annuli in va places. From Gaillard Cut, near Las Cascadas (station 6020*a*).

5



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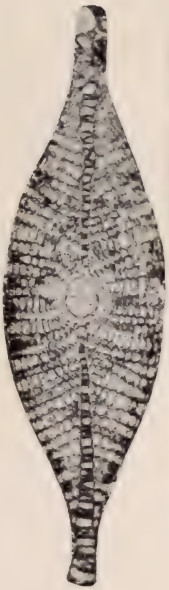

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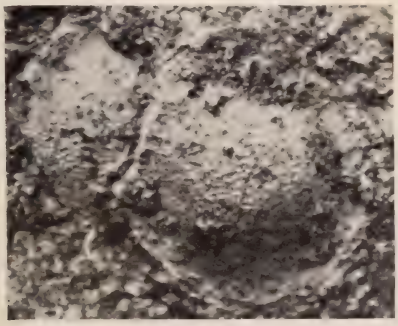

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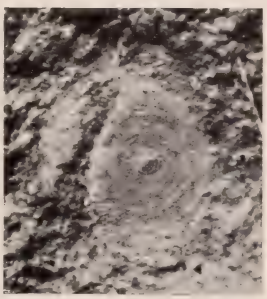

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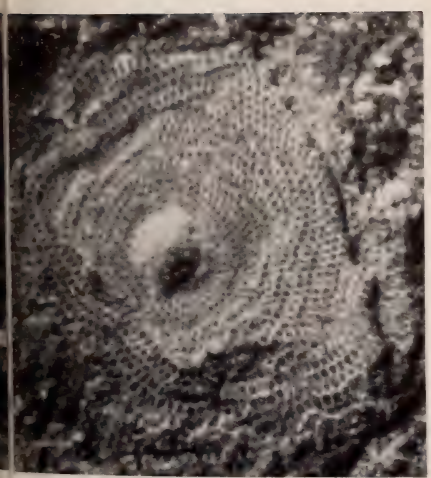

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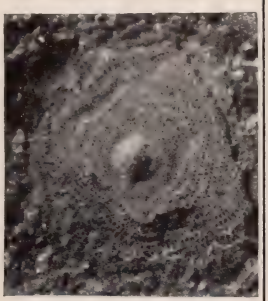
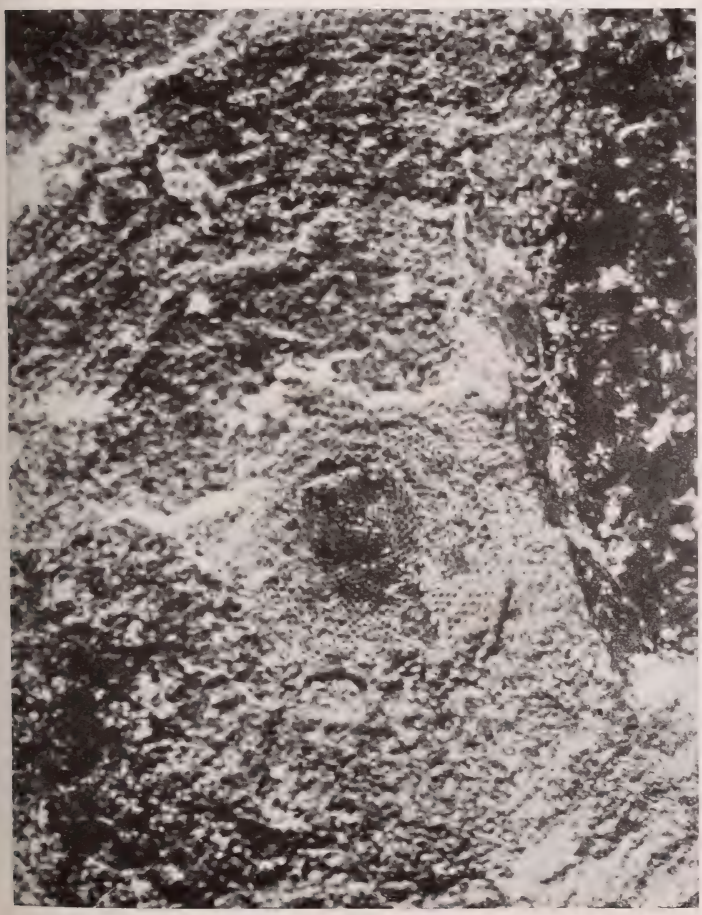


3a

LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGES 99–100.

2 1



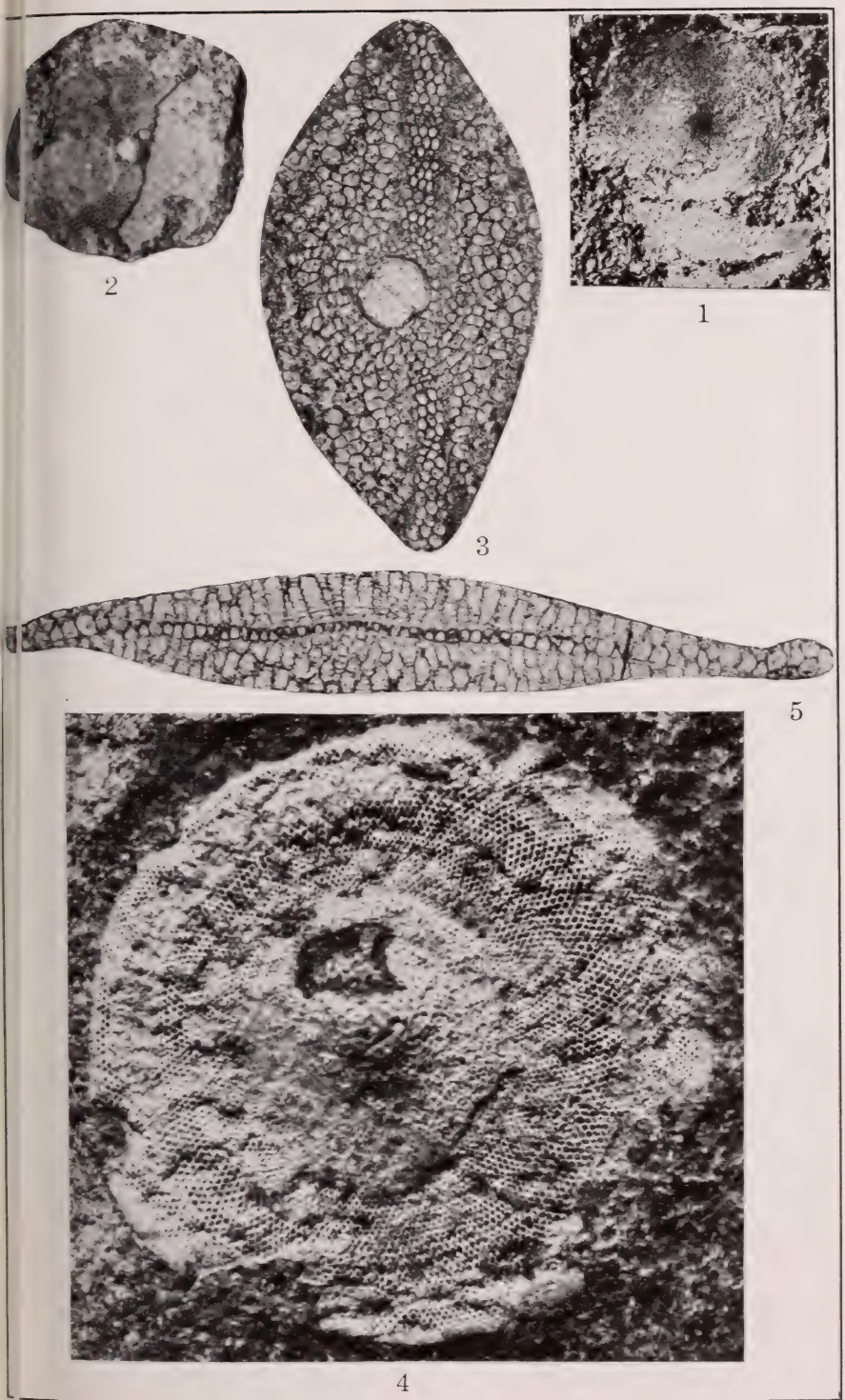
3

LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 100.

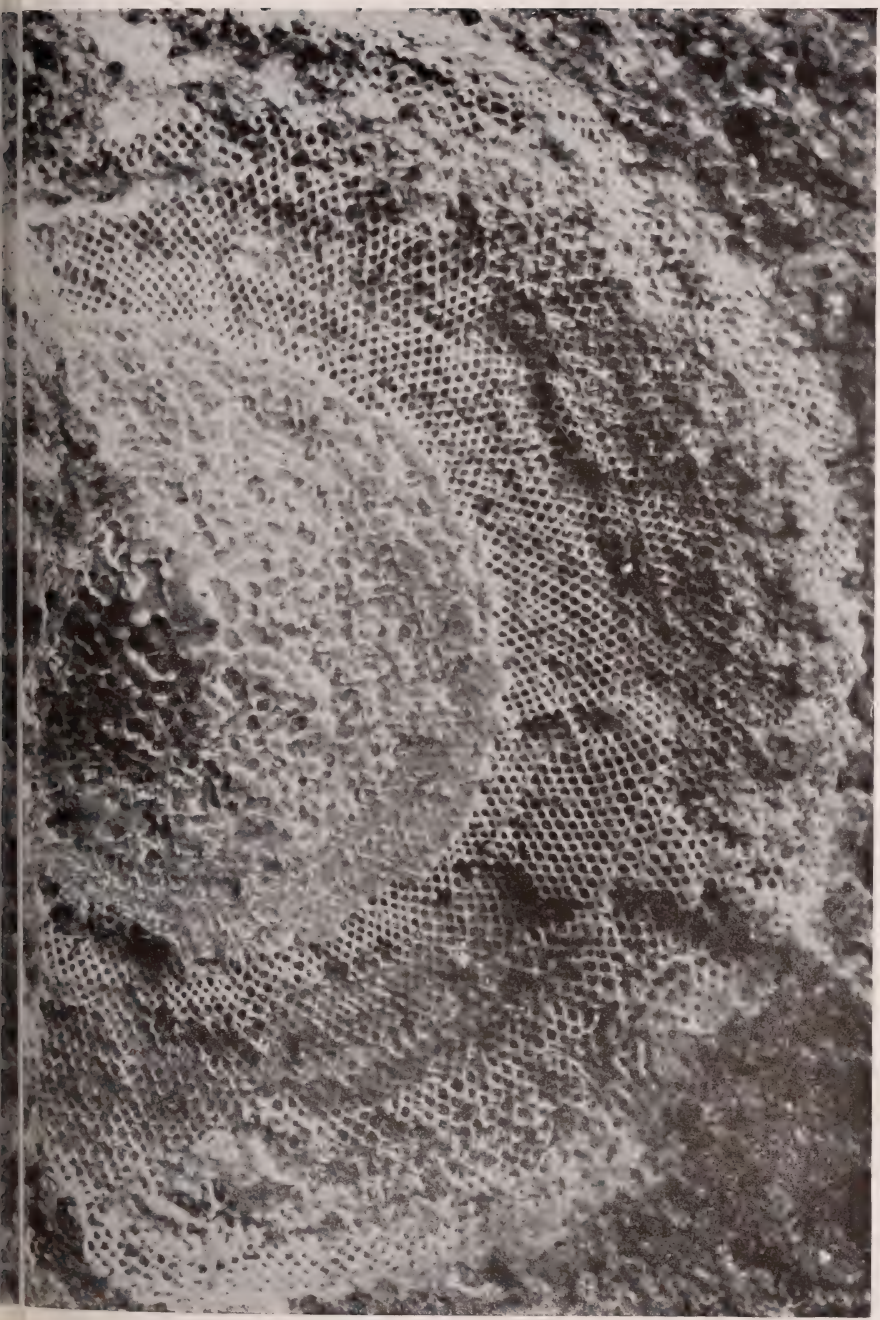
LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 100.



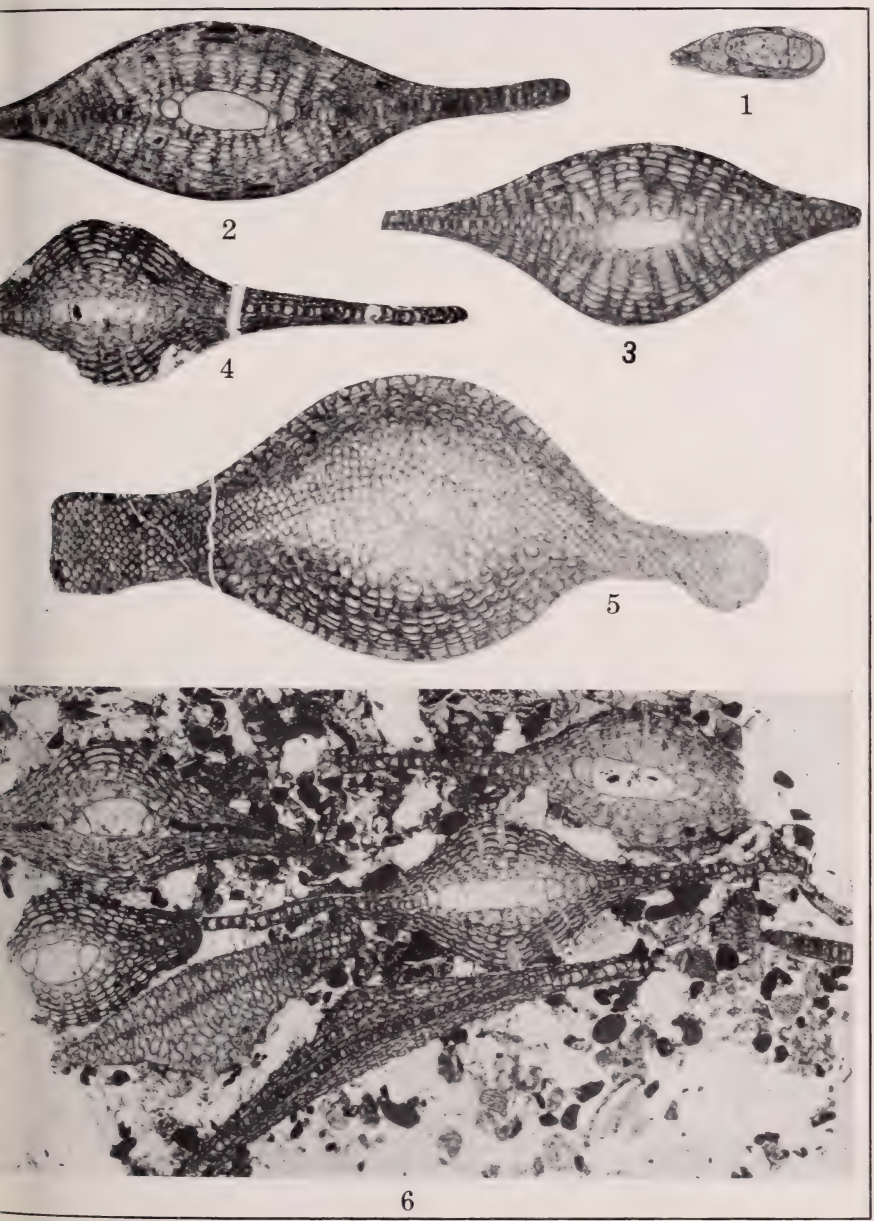
LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 100



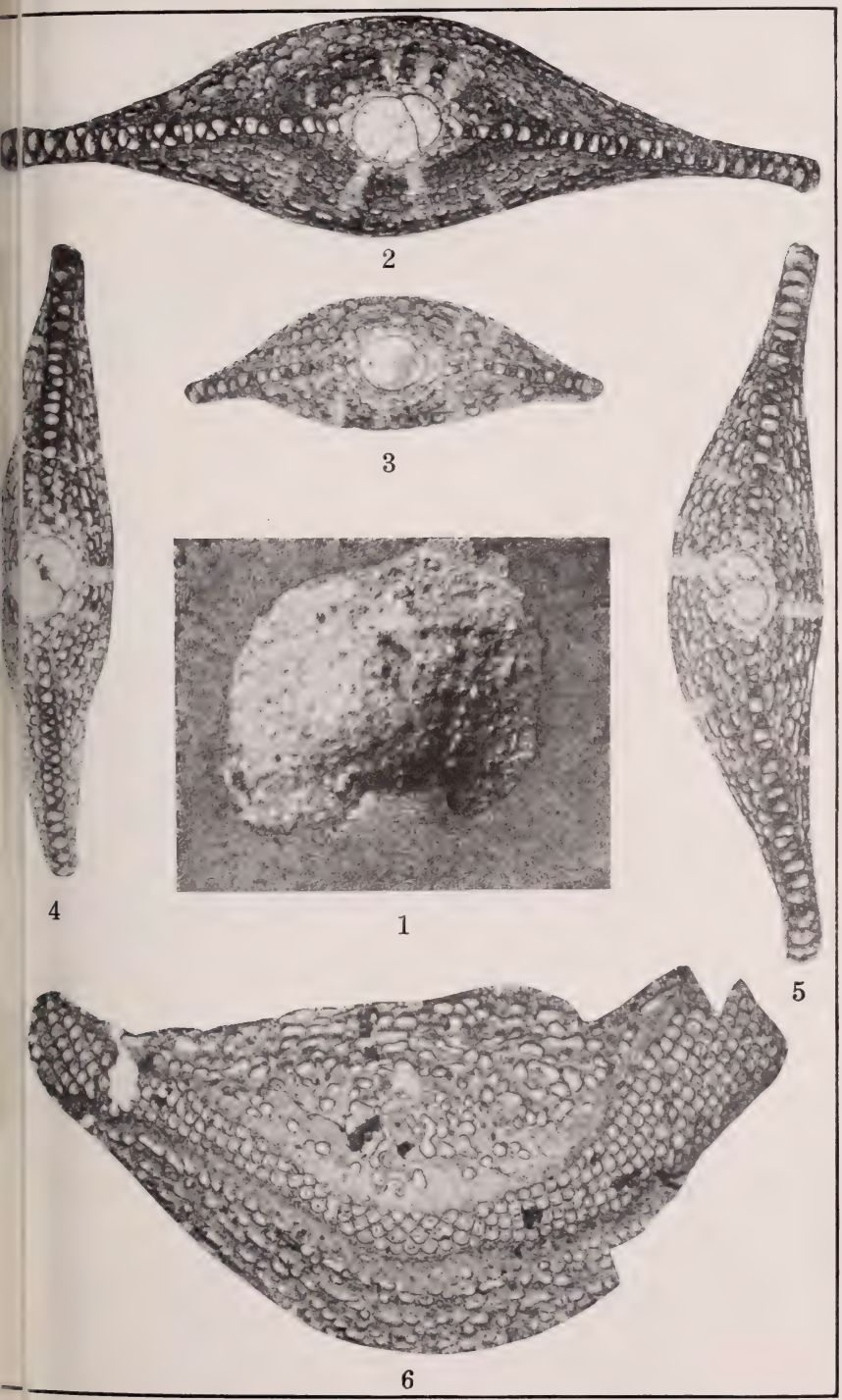
LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 101



LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 101



LARGER FOSSIL FORAMINIFERA FROM PANAMA.

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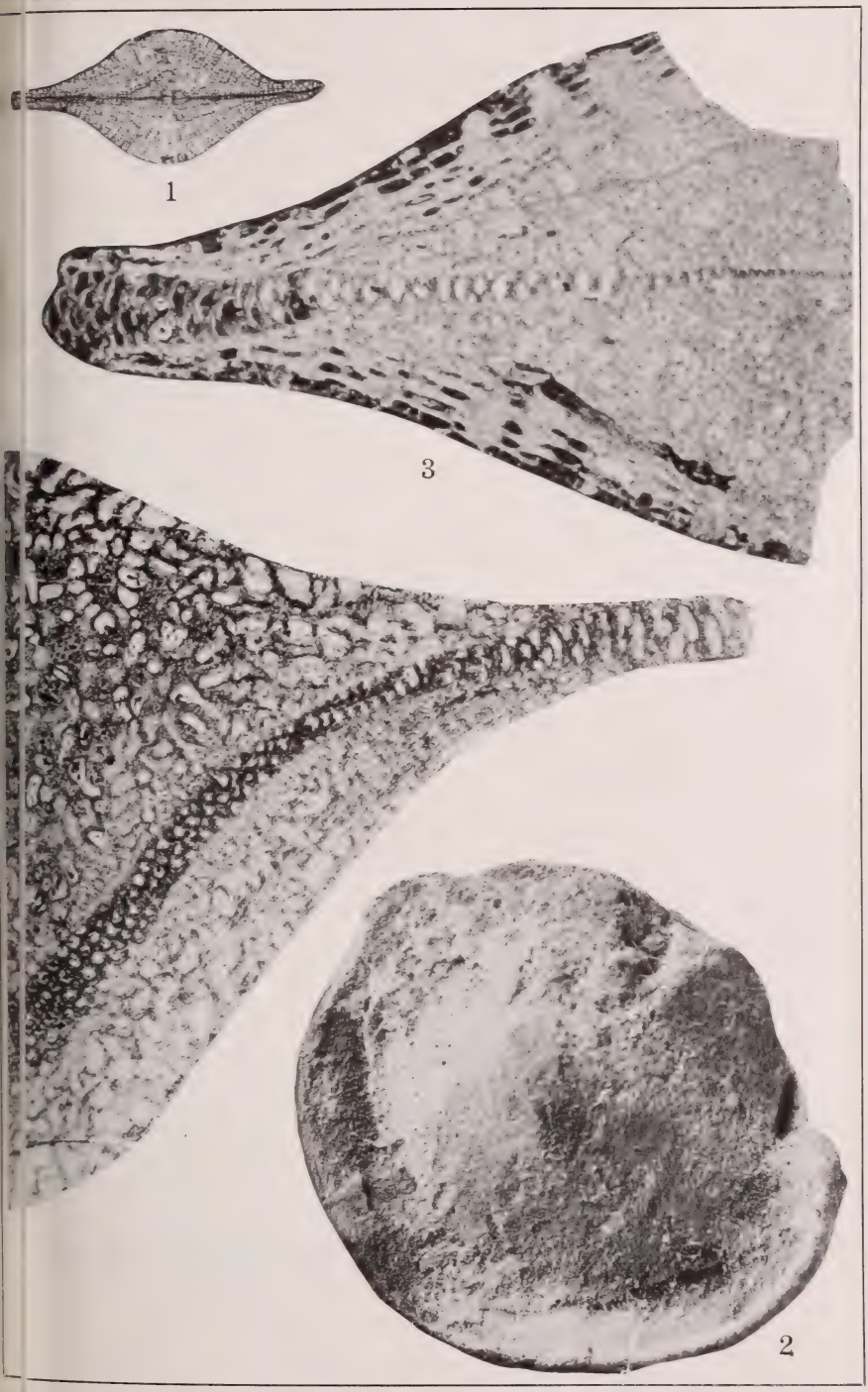
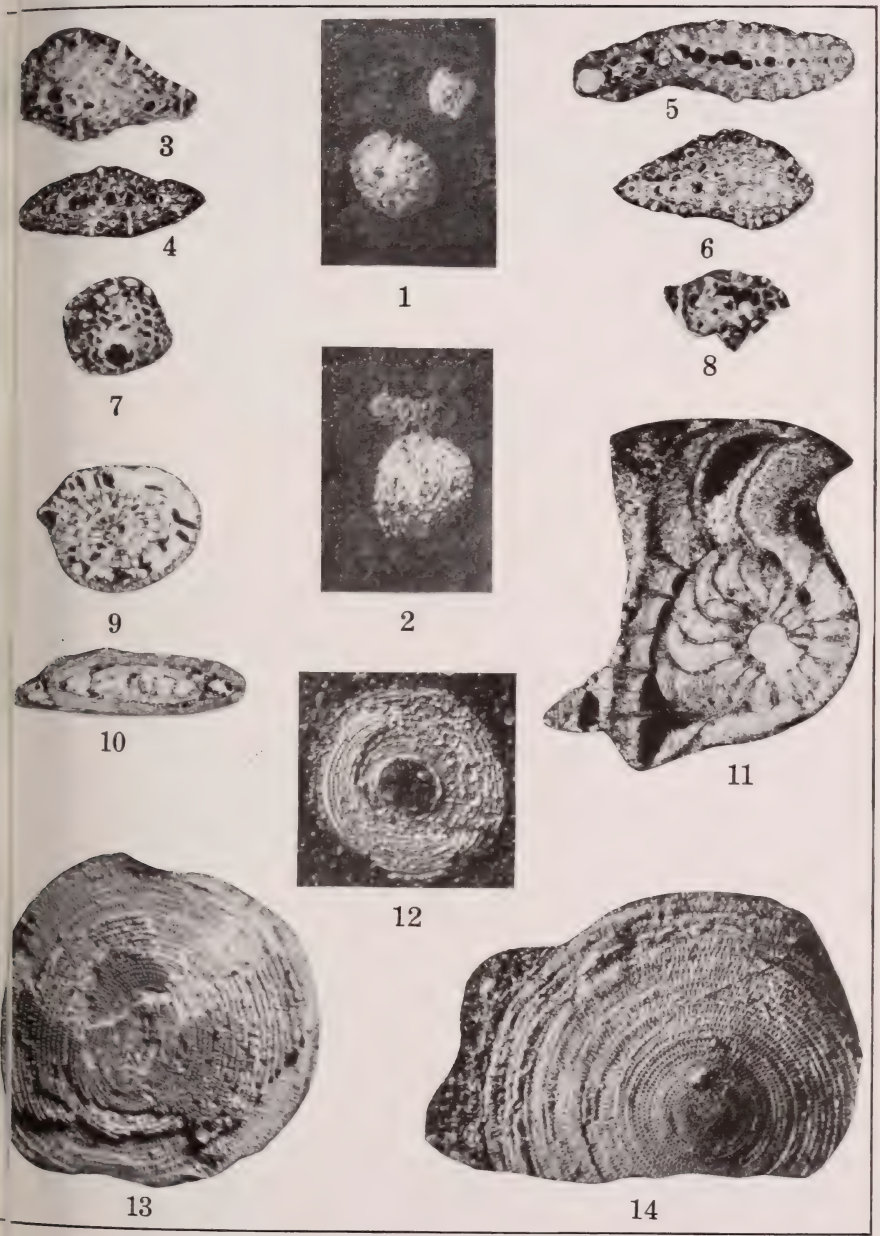


LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGES 101, 102.

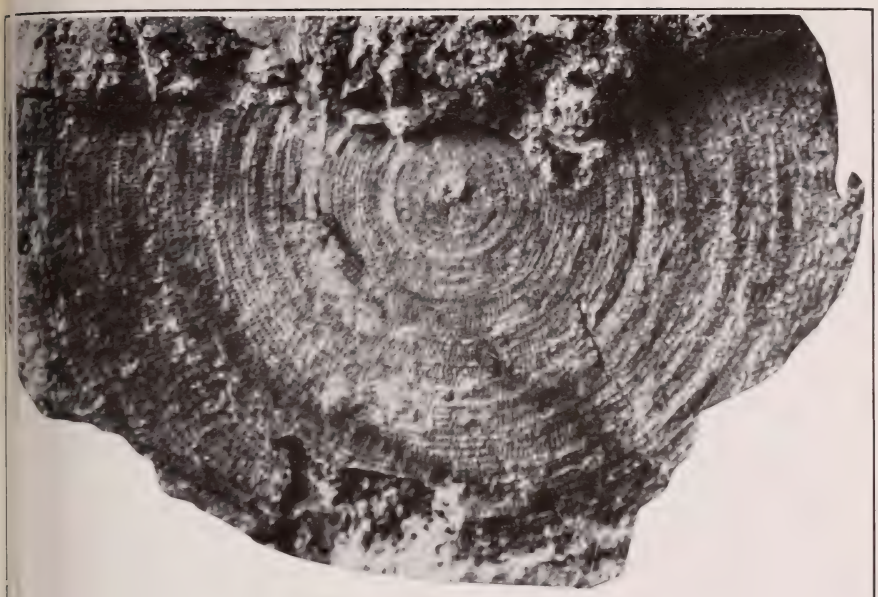
LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 102.



LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 102.



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LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 102.

LARGER FOSSIL FORAMINIFERA FROM PANAMA.

FOR EXPLANATION OF PLATE SEE PAGE 102.

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

ONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

OSSIL ECHINI OF THE PANAMA CANAL ZONE AND COSTA RICA

By ROBERT TRACY JACKSON
Of Peterborough, New Hampshire

Extract from Bulletin 103, pages 103–116, with Plates 46–52

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1918

FOSSIL ECHINI OF THE PANAMA CANAL ZONE AND COSTA RICA.

By Robert Tracy Jackson,

Of Peterborough, New Hampshire.

INTRODUCTION.

The following is essentially a reprint of my paper bearing the me title published in the Proceedings of the United States National useum, volume 53, pages 489–501, plates 62–68, September 24, 1917: The fossil echini of the Panama Canal Zone were submitted to me r study and description by Dr. T. Wayland Vaughan as part of the udies he is making in that region in connection with his investiga- ons of the geology of the Costal Plain of the United States and of e West Indies. The material contains some very interesting ecies, particularly in the genus *Encope*, of which there are three w forms. Some of the material is well preserved, and parts are agmentary. A number of specimens too poorly preserved, or too agmentary for specific determination, indicate that a more ex- nsive echinoid fauna may be found by further search.

I wish to express my heartiest thanks to my friend, Dr. Hubert yman Clark, of the Museum of Comparative Zoölogy, who, with his eat knowledge of Clypeastroids and Spatangoids, helped me aterially in preparing this report.

LIST OF SPECIES AND THEIR GEOLOGIC OCCURRENCE.

lypeaster lanceolatus Cotteau. Upper Oligocene, Emperador lime- stone, Gaillard Cut, stations 5866*b*, 6671.

lypeaster gatuni Jackson. Miocene,[1] Gatun formation, station 5662, near Gatun Dam site; and at station 6237, north of Ancon Hill, about 4 miles south of Diablo ridge.

ncope annectans Jackson.[1] Miocene, Gatun formation, station 5846, Spillway, Gatun Dam.

ncope platytata Jackson. Miocene,[1] Gatun formation, station 6029*a*, one-quarter to one-half mile from Camp Cotton, toward Monte Lirio.

[1] This formation is more appropriately referable to the lower Miocene, i. e., Burdigalian, an to the upper Oligocene.—T. W. V.

Encope megatrema Jackson. Miocene,[1] Gatun formation, stat n 6030, about one and one-half miles from Camp Cotton, tow:d Monte Lirio.

Echinolampas semiorbis Guppy. Upper Oligocene, Emperador li: stone, Gaillard Cut, stations 5866*b* and 6019*g*.

Schizaster armiger W. B. Clark. Miocene(?),[1] Bonilla, Costa Ri

Schizaster cristatus Jackson. Miocene(?),[1] Brazil, Costa Rica, s tion 5505.

Schizaster panamensis Jackson. Miocene,[1] Gatun formation, n Gatun, at stations 6008 and 7294.

DESCRIPTION OF SPECIES.

CLYPEASTER LANCEOLATUS Cotteau.

Plate 46, figs. 1, 2.

Clypeaster lanceolatus, COTTEAU, Descripcion de los Equinoides Fossiles Isla de Çuba, Bol. Com. del. Mapa Geologico de Espana, vol. 22, 189 39, pl. 9, figs. 1, 2, 3.—JACKSON, Proc. U. S. Nat. Mus., vol. 53, 191 490, pl. 62, figs. 1, 2.

This species is one of the few in the series from the Panama Ca Zone that seems referable to an already published species. Th are seven specimens, all in good condition of preservation and re senting two localities which, however, from the character of material may be nearly associated. I give measurements of largest specimen of the set. Length, 95 mm.; width, 77mm.; hei 21 mm. Test elongate, wider behind than in front, moderately vated, deeply concave in ventral view. Ambulacral petals eleva distally acuminate, nearly closed and pinched up as if squee between the thumb and finger. Anterior petal III equal in len to petals I and V and a few millimeters longer than are the ante pair II and IV. The anterior petal III is more widely separated f petals II and IV than are those latter from I and V. Interporife areas of petals are elevated, wide, being about equal to both po erous areas. Interambulacra are narrow, extremely so near apical disk. Tubercles are small and of about the same size dors and ventrally. Apical disk is central, mouth central, deeply sunl periproct ventral, about four mm. from the posterior border of test. The original material described by Cotteau is from the "M cene" of Matanzas, Cuba, where he says it is very rare. It is ap ently more or less common in the Canal Zone, as there are seven sp mens from that region.

[1] This formation is more appropriately referable to the lower Miocene, i. e., Burdig than to the Upper Oligocene.—T. W. V.

Localities and geologic occurrence.—Upper Oligocene; Emperador limestone. Upper Limestone, Las Cascadas, Panama, D. F. MacDonald, collector, U. S. National Museum station No. 6671, two specimens, U. S. Nat. Mus. Cat. No. 324452; also Panama Canal Zone, Upper Limestone bed, near Tower "N" (opposite Las Cascadas, Gaillard Cut) D. F. MacDonald, collector, 1911, U. S. National Museum station No. 5866 *b*, five specimens, U. S. Nat. Mus. Cat. No. 324451.

CLYPEASTER GATUNI Jackson.

Plate 47, fig. 1; plate 48, fig. 1.

Clypeaster gatuni JACKSON, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 491, pl. 63, fig. 1; pl. 64, fig. 1.

This species is represented by a fine, large specimen in perfect condition of preservation. Two additional specimens much worn and incomplete are also referred to it.

The type measures 146 mm. in length, 122 mm. in width, and 35 mm. in height. The test is elongate, moderately pentagonal in outline, with slight incurving of the borders in interambulacral areas 2, 3, and 4. Its greatest width is across ambulacra II and IV. Ventrally the test is deeply concave, being flat only on the border. The ambulacral petal III is equal in length to petals I and V and a few millimeters longer than are petals II and IV. The petals are subdistant, highly elevated, and open at their distal ends. Ventrally, the deep ambulacral grooves extend to the mouth. Interambulacra are broad on the border of the test, narrowing up dorsally and very narrow near the apical disk. Each of the interambulacra between the petals are strongly elevated as if pinched up. The apical disk is slightly anterior to the middle of the test and is very small. The mouth is central, deeply sunken. The periproct is ventral, slightly elliptical, its posterior border 5 mm. from the posterior limits of the test. Tubercles are small, covering the dorsal surface of the test, ventrally the same, but slightly larger.

Clypeaster gatuni approaches nearest, perhaps, to *C. bowersi* Weaver, but it differs in the shape of the test, the deeply concave base, the shape and proportionate size of the petals and interambulacra dorsally, and the fact that the periproct is ventral instead of terminal.

Locality and geologic occurrence.—Gatun formation, Miocene. Panama Canal Zone, near Gatun Dam site, D. F. MacDonald, collector, 1911, holotype, U. S. National Museum, station No. 5662, one specimen.

Limestone in swamp, north of Ancon Hill, about 4 miles south of Pablo Ridge in the upper Oligocene Emperador limestone, U. S. National Museum, station No. 6237, two specimens.

Holotype.—Cat. No. 324453, U.S.N.M.

This species is present on both the Atlantic and Pacific sides of the Isthmus.

ENCOPE ANNECTANS Jackson.

Plate 49, figs. 1, 2; plate 50, fig. 1.

Encope annectans Jackson, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 491, t
fig. 1; pl. 65, figs. 1, 2; pl. 66, fig. 1.

This interesting species is represented by three specimens wh
include two tests free from matrix and more or less complete, a
a sandstone mould of the exterior of the ventral side of a specim
which is the largest of the three.

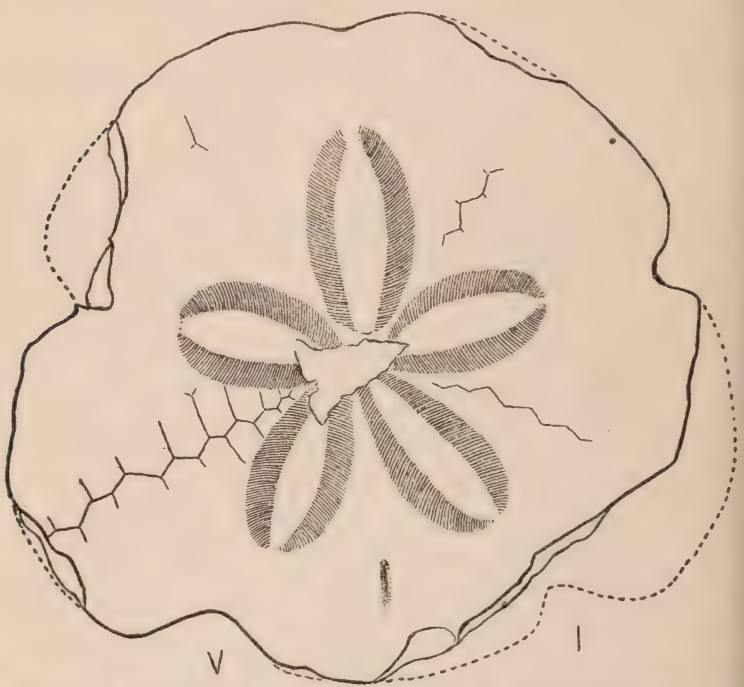


Fig. 1.—Encope annectans. Drawing of the type-specimen, natural size. Resto
parts are indicated by dotted lines.

In shape, the specimens are thin, flattened, and nearly circular
outline, excepting for the reëntrant marginal ambulacral notch
The edges are thin, exceptionally so for the genus, and the wh
test superficially is scutelliform. In the anterior ambulacrum
there is a shallow rounded notch, and in the lateral ambulacra
deeper and narrower notches, the deepest being in the posterior p
of ambulacra, IV and V. The apical disk is central. The peristo
is small and also central. Continuing posteriorly from the p
stome on the ventral side is a quite deep groove, and on the dor
side is a shorter and shallower groove. These grooves do not fo
a hole through the test, but represent the incipient beginnings of

nule which is characteristic in *Encope* of the posterior interambula-
m 5. This is most interesting and is discussed later at length.

The type-specimen measures 86 mm. in length, 89 mm. in width, d 8 mm. in height. The highest point is distinctly anterior to the ddle of the test. The specimen represented by a mould of the ntral side is somewhat larger than the type. It measures about mm. in length by about 96 mm. in width.

In the type, the ambulacral petals are broad, about equal in length the several areas, the posterior pair extending back to a line with e anterior limit of the lunule in interambulacrum 5. Ventrally, the bulacral furrows are deep, slightly curved outward from the dian line of each ambulacrum, forking near the border of the test, h furrow giving off a forked branch at nearly a right angle to the in furrow. The apical disk is central, but details are obscured ing to local imperfections in both specimens showing the dorsal e. Interambulacral areas are narrow in the petaloid areas, wide r the margin of the test. The whole dorsal surface of the test is ered with small tubercles; on the ventral side of the test the ercles are somewhat larger, but they are reduced in size or want- along the lines of the ambulacral furrows. The mouth is small l central in position. The periproct is small, oval in outline, and ated at nearly one-third the distance from the mouth to posterior der of the test.

he lunule of interambulacrum 5 is the remarkable and most in-esting feature of this species. Ventrally, it consists of an im-ssed area 15 mm. long by 2 mm. wide, extending to and being fluent with the opening of the periproct. Dorsally, the lunule consists of an impressed area lying above the middle of the ven- lunular depression and measuring 10 mm. in length by 2 mm. in dth. This is the only species in the genus recorded in which the lule fails to make an opening through the test. Structually, it most interesting, as it closely resembles the condition in a young cimen of *Mellita sexiesperforata* (Leske) from the west coast of rida, 30 fathoms, No. 2900, Museum of Comparative Zoölogy. s young *Mellita*, which measures 9 mm. in length, has no notches unules as yet developed in the ambulacral areas, but in interam-crum 5, as viewed ventrally, there is a distinct impressed area rking the initial beginnings of a lunule as in our specimen of adult *ope annectans*. It should be stated that this specimen of *Mellita* robably exceptional in holding this youthful character so late, as small series of younger specimens of *M. sexiesperforata* measur-from 4 to 7 mm. in length, all have a perforate lunule in interam-crum 5. This latter set is from Salt Key, Bahamas, No. 2439, eum of Comparative Zoölogy. As pointed out by Mr. Agassiz vision of the Echini, pp. 320–324) in *Mellita sexiesperforata*, the

ambulacral and interambulacral lunules develop by resorption thro the test, whereas in the other species of *Mellita*, as far as known, ambulacral lunules are developed by the inclusion of marg notches and the interambulacral lunule alone is formed by invag tion through the test.

Encope annectans is primitive like the other fossil species of Enc in that the ambulacral notches are not inclosed to form lunules are still shallow and open. It is undoubtedly the most primitiv the genus in that the lunule in interambulacrum 5 is still im forate. It makes an approach to the Recent *Encope miche* Agassiz of the Gulf of Mexico and *E. grandis* Agassiz of the Gul California which are the only living species characterized by o marginal notches. On the other hand, *E. annectans* resembles *cope micropora* Agassiz of the West Coast in the form of the and the position of the interambulacral lunule.

Locality and geologic occurrence.—Gatun formation, Mioc Panama Canal Zone, Spillway at Gatun Dam site, D. F. MacDon collector, U. S. National Museum station No. 5846, three specimen

Type.—Cat. No. 324454, U.S.N.M. *Paratype.*—Cat. No. 324 U.S.N.M.

ENCOPE PLATYTATA Jackson.

Plate 51, figs. 1, 2.

Encope platytata Jackson, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 494, tex 2; pl. 67, figs. 1, 2.

There is only a single specimen representing this species, while it is imperfect, it yet has the essential parts preserved that necessary for a description. As in the last described species, *E. nectans*, this species, *E. platytata*, is thin, flattened, and if comp apparently would be nearly circular in outline excepting for the bulacral notches. If complete, the specimen would measure as mated about 100 mm. in length and 100 mm. in width. The grea height of the test is in the apical region, where it measures 10 As the ventral side of the test is somewhat concave instead of b flat, the thickness of the test at the center, as measured by cali is somewhat less than the height and measures only 8 mm.

The anterior ambulacral notch of area III is very shallow rounded. The notches of the lateral anterior ambulacra II and are also rounded but deeper than the notch of area III. Presum the notches of the posterior ambulacra I and V, if preserved, w be similar but somewhat deeper, as this is the usual characte associated species. The lunule in interambulacrum 5 is small, passes directly through the test instead of being imperforate a *Encope annectans*. This lunule is only preserved for the ante part of its extent as shown in the figures. The mouth is small

tral in position, the periproct is elongate oval, its anterior border
3 mm. posterior to the border of the mouth opening. Poste-
ly the periproct is confluent with the infolded depression of the
rambulacral lunule.

he ambulacral petals are rather narrow in this specimen, measur-
13 mm. in width. The odd anterior ambulacral petal is longer
n the others, and measures 36 mm. in length, whereas the pos-
or petals of the trivium measure 28 mm. in length. The petals
he bivium, or I and V, are longer than the posterior pair of the

2.—Encope platytata. Drawing of the type-specimen, natural size. Restorations are indicated by dotted lines.

ium, but as they are incomplete posteriorly, a measurement can
be given. On the ventral side, the ambulacral furrows are
gly marked and each gives off a few weakly impressed branches.
he apical disk is quite well preserved, shows clearly the ocular
s and four of the five genital pores, which are a characteristic
re of *Encope*. The only genital pore wanting is that occurring
ea 1, which is destroyed by a local fracture of the test. Minute
cles cover the dorsal side of the test. Ventrally the tubercles
rger except near the ambulacral furrows where they are minute.

Encope platytata is a near ally of *Encope tenuis* Kew[1] of the Miocene of California, but differs from that species in that the greatest height of the test is central, and the periproct is confluent with the lunule.

Locality and geologic occurrence.—Gatun formation, Miocene, Panama Canal Zone, from lowest horizon in big cut, one-fourth to one-half mile beyond Camp Cotton toward Monte Lirio, D. F. MacDonald and T. W. Vaughan, collectors, 1911, U. S. National Museum station No. 6029*a*, one specimen.

Type.—Cat. No. 324455, U.S.N.M.

ENCOPE MEGATREMA Jackson.

Plate 52, fig. 1.

Encope megatrema JACKSON, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 49, text figs. 3, 4; pl. 68, fig. 1.

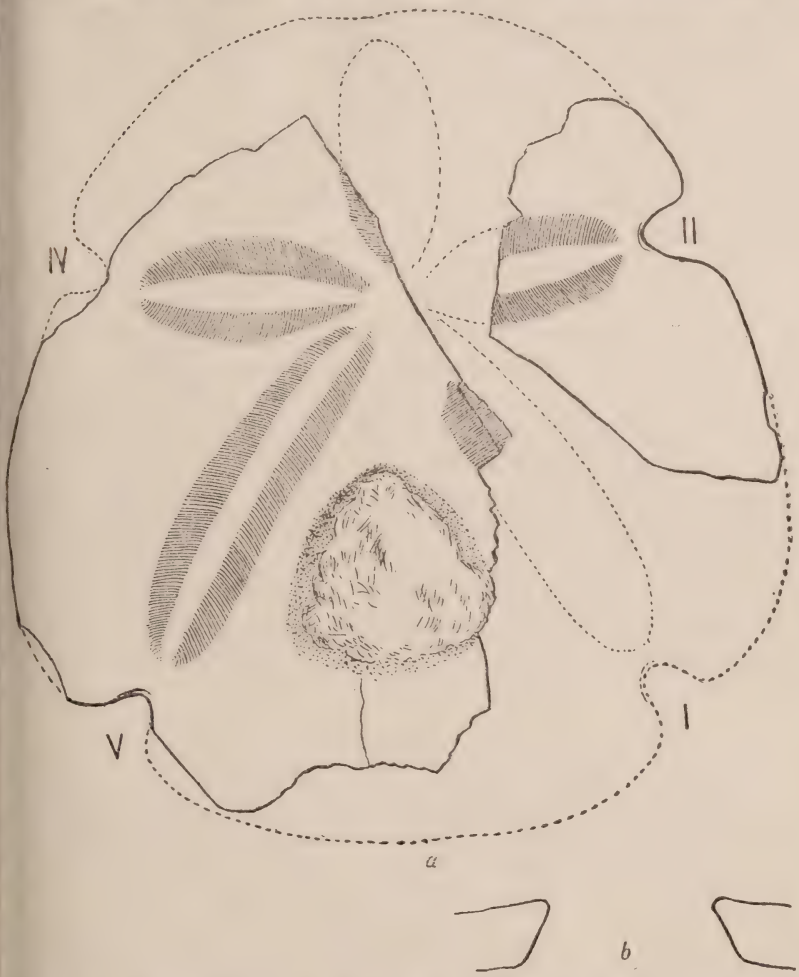
This species is represented by one fairly good test with its corona part, and in addition some 12 fragments which yield helpful data on close study. From the incompleteness, measurements and many details will have to be given in general terms or omitted. As a whole the test is low, elongated, thin on the borders and with shallow ambulacral notches and an enormous lunule in interambulacrum 5.

From the best specimen, which is figured, the length probably was about 120 mm. and the width about 106 mm.; thickness of the test at its center is 10 mm. Ambulacral notches are shallow and not wide in areas II and V, indicating that this is the character in the two posterior ambulacra I and V and also in the paired anterior ambulacra II and IV. This evidence is supported by several of the fragments which show shallow lobes like the type, but it can not be definitely stated which areas they represent. The notch of the anterior odd ambulacrum III is not known, but it was probably shallower than the others, as is characteristic of species of the genus. The most striking feature of this species is the lunule in interambulacrum 5 which is enormous. It is situated about midway between the apical disk and posterior limits of the test, and is roughly triangular in shape, the apex of the triangle pointing anteriorly. It measures on the surface of the opening 27 mm. in length and 27 mm. in width at the widest part posteriorly. The walls of the lunule slope outward from the center, as seen looking from above, as is well shown in two of the fragmentary specimens. From this sloping character of the walls, it results that the width of the lunule would be greater by about 6 to 10 millimeters on the ventral side than it is on the dorsal. The height of the wall of the lunule is 12 mm., which is doubtless the highest point of the test. The lunule in this species is, relatively to the size of the specimens, the largest known in any species of the

[1] Kew, W. S. W. Tertiary echinoids of the Carrizo Creek Region in the Colorado Desert. University of California Bull., Dept. Geology, vol. 8, No. 5, pp. 39–60, pls. 1–3, 14.

nus, fossil or living. It is striking that this great size of the lunule, progressive character, should be associated with small and shallow mbulacral notches which, for the genus, is a relatively primitive aracter.

The ambulacral petals are beautifully distinct and well preserved r part of their extent in the type and one other specimen. The



G. 3.—*a*, ENCOPE MEGATREMA. HOLOTYPE, NATURAL SIZE. THE AREA SHOWING PART OF AMBULACRUM II IS DRAWN FROM A FRAGMENT. RESTORATIONS ARE INDICATED BY DOTTED LINES. *b*, SECTION OF LUNULE TO SHOW THE INCLINED FACES, DRAWN FROM TWO FRAGMENTS.

sterior pair, I and V, are long and narrow with a relatively wide riferous area and narrow median interporiferous area. The width the petal of ambulacrum V is 11 mm. and its length is 50 mm. It tends posteriorly in a wide curve around the lunule of interambucrum 5 and reaches a line coincident with the posterior end of the

lunule. It also extends to within 5.5 of the ambulacral notch of
area in which it lies. Ambulacrum IV is much shorter than amb
crum V, measuring 30 mm. in length and 12 mm. in width at
widest part. This ambulacrum extends to within 3.5 mm. of
marginal notch. The features of the ambulacra V and IV, as
scribed, indicate the character of ambulacra I and II, which are
preserved in part in the holotype, though one of the fragments
ambulacrum II quite perfectly preserved. Ambulacrum III is re
sented only in part (for a length of 25 mm.) by the left side of
petaloid area; it probably had about the length and width of
petal of ambulacrum IV, as in the allied species *Encope macroph*
Ravenel. Ambulacral furrows on the ventral side are deep, stron
marked, with some forking near the periphery of the test. The in
ambulacra are very wide, not narrowing markedly near the ap
disk. Minute tubercles cover the dorsal surface of the test, and
trally the tubercles are larger excepting on the lines of ambula
furrows, where they are minute or wanting. Details of the ap
disk, peristome and periproct are entirely wanting. This species
not make a close approach to any other known species, but its nea
ally is *Encope macrophora* Ravenel from the upper Miocene
South Carolina and the Pliocene of Florida.[1]

Locality and geologic occurrence.—Gatun formation, Mioc
Panama Canal Zone. From 85-foot cut north side of big swamp
relocated line, Panama R. R., about one and one-half to two m
beyond Camp Cotton, toward Monte Lirio, D. F. MacDonald
T. W. Vaughan, collectors, 1911. Fourteen specimens, includ
fragments, U. S. National Museum station No. 6030.

Type.—Cat. No. 324456, U.S.N.M.

ECHINOLAMPAS SEMIORBIS Guppy.

Echinolampas semiorbis Guppy, On Tertiary Echinoderms from the W
Indies, Quart. Journ. Geol. Soc. London, vol. 22, 1866, p. 299, pl.
fig. 7.—Cotteau, Echinides Tertiares des Iles St. Barthélemy et
guilla, Kongl. Svensk. Vetenskaps. Akad. vol. 13, 1875, p. 24, p
figs. 1–2; pl. 6, fig. 1.—Jackson, Proc. U. S. Nat. Mus., vol. 53, 1
p. 498.

This species is abundant in the Oligocene Tertiary of the W
Indies, material from Anguilla having been described by Guppy,
Cotteau erroneously records it from St. Bartholomew. Dr. T. W
land Vaughan in 1914 collected abundant, fine specimens in the Isla
of Anguilla.

From the Panama Canal Zone a number of specimens were
lected from a hard gray limestone. The specimens are for the m
part uncompressed and in very good condition of preservation.

[1] Clark, William Bullock, and Twitchell, Mayville W. Mesozoic and Cenozoic Ech
dermata of the United States. Monograph, U. S. Geol. Survey, vol. 54, 1915, p.
pl. 93, figs. 2*a–e*; pl. 94, figs. 1*a–f*.

he largest specimens measures 107 mm. in length, 103 mm. in th, and 53 mm. in height.

ocality and geologic occurrence.—Upper Oligocene. Emperador stone, Panama Canal Zone. Upper Limestone bed near Tower (opposite Las Cascadas, Gaillard cut), D. F. MacDonald, col- r, 1911, U. S. National Museum station No. 5866*b*, one specimen, . Nat. Mus. Cat. No. 324457. Also Panama Canal Zone, from 5th opmost limestone, Gaillard cut, opposite Las Cascadas, U. S. onal Museum station No. 6019*g*, D. F. MacDonald and T. W. ghan, collectors, 1911, 4 specimens. U. S. Nat. Mus. Cat. No. 58.

SCHIZASTER ARMIGER W. B. Clark.

Schizaster armiger CLARK and TWITCHELL, Mesozoic and Cenozoic Echinodermata of the United States, Monograph U. S. Geol. Survey, vol. 54, 1915, p. 152, pl. 70, figs. 1*a–d*.—JACKSON, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 498.

this species the test is rather large, cordiform; upper surface es at first rapidly, then more slowly from the anterior margin to apical system beyond which an elevated sharp ridge continues to truncated posterior margin. Length, 59 mm.; width, 50 mm.; ht. 25 mm. The ambulacra are broad and the odd anterior ulacral petal III is situated in a deep groove that indents the rior margin. The two lateral anterior ambulacra II and IV are eep, broad grooves, with petals 18 mm. long. The posterior ulacra I and V, similar but shorter, are 9 mm. long. Peripetalous iole is broad and distinct. Interambulacra gibbous, the posterior 5 being built up into an elevated keel. The peristome is indis- in our specimen, but as shown in W. B. Clark's excellent figures, ide and near the anterior margin. The periproct is high on the cated posterior end.

ıe type material described by Clark is ascribed to the upper kson) Eocene of Choctaw County, Alabama.

ocality and geologic occurrence.—Miocene(?),[1] Bonilla, Costa . Hill collection, U. S. Nat. Mus. Cat. No. 135214, one specimen.

SCHIZASTER CRISTATUS Jackson.

Plate 52, figs. 2–4.

Schizaster cristatus JACKSON, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 499, pl. 68, figs. 2–4.

ıe material of this species consists of two internal moulds; as the es are entirely wanting, of course external characters can not be n. The more perfect of the two specimens measures 40 mm. in th, 36 mm. in width, and 22 mm. in height. Test is moderate

[1] cording to Hill and Dall the rocks exposed at this locality are of the same age as at Gatun, Canal Zone. For a further discussion see the last chapter (by Vaughan) s volume.

sized, cordiform, sloping gradually from the anterior border up to the median crest, the widest portion being through the middle of the test. The most striking feature of this species is the median keel-like crest that rises sharply from the summit of interambulacrum 5 at the posterior border of the test.

The petal of ambulacrum III is sunken in a deep, wide groove extending to the anterior border of the test and measuring 23 mm. in length. The petals of the lateral anterior ambulacra II and IV are in deep grooves measuring 13 mm. in length and having about 28 plates in each half ambulacrum, as is indicated by the casts of the pores. The petals of the posterior ambulacra I and V are widely divergent from the anterior pair, nearly parallel and directed backward in deep, sunken grooves. The grooves are 7 mm. long, and there are about 14 plates in each half ambulacrum at this point as indicated by casts of the pores. The periproct is situated on the posterior face and coincides with the base of the crest in interambulacrum 5. The peristome is wide and situated far forward, the tip which almost closes the mouth being 10 mm. from the anterior border of the test.

Locality and geologic occurrence.—Miocene(?), Brazil, Costa Rica, A. Alfaro, collector, U. S. National Museum station No. 5505, two specimens.

Type.—Cat. No. 324460, U.S.N.M.

SCHIZASTER PANAMENSIS Jackson.

Plate 50, figs. 2–3.

Schizaster panamensis Jackson, Proc. U. S. Nat. Mus., vol. 53, 1917, p. 10, pl. 66, figs. 2, 3.

The material consists of an internal mould free from matrix, and three specimens more or less complete, embedded in porous, dark-colored volcanic tuff which also bears some fragments of lignite. The specimen, free from matrix, is the most completely preserved, although somewhat compressed dorso-ventrally, and is selected as the type. The specimen measures 48 mm. in length, 40 mm. in width, and 25 mm. in height. The petals of the ambulacra are situated in broad, deep furrows. The anterior petal III extends to the anterior limit of the test and measures 23 mm. in length. The paired anterior ambulacra II and IV are in grooves 13 mm. long and diverge widely from the anterior petal. The posterior petals I and V are shorter than the anterior pair, measuring 5 mm. in length, and are directed almost straight backward. The position of the periproct is not clearly indicated on the mould, but apparently it is near the upper part of the posterior face. The peristome is wide and rounded, and is situated 16 mm. from the anterior border of the test. The pi-

lous fasciole is quite wide and is fairly well shown in areas II IV on the type-specimen and still better in one of the fragments, ch is a counterpart of the dorsal side of the same.

ne of the specimens, which is an external mould, shows the im- s of the outline of the plates of part of a test, and gives measure- ts of considerable interest. It measures about 50 mm. in length, t 45 mm. in width, and about 38 mm. in height. From incom- leness of the specimen no exact measurements can be given, yet e available indicate a very high test.

ocality and geologic occurrence.—Gatun formation, Miocene, ama Canal Zone. Second cut, south of Gatun R. R. Station, lman Coll., U. S. National Museum station No. 7294, four speci- s. Holotype, U. S. Nat. Mus. Cat. No. 324461. Another speci- , imperfect and much worn, with a very high test, and appar- y referable to this species, is from Panama Canal Zone, Gatun, on A, from middle of Bed "E," D. F. MacDonald, collector, U. S. onal Museum station No. 6008, one specimen. U. S. Nat. Mus. No. 324462.

DESCRIPTION OF PLATES.

PLATE 46.

FIG 1. *Clypeaster lanceolatus* Cotteau, dorsal view, natural size. The dark spot in interambulacrum 5 is a yellow label that took black in the photograph.: U. S. Nat. Mus., Cat. No. 324451, Station 5866*b*.

2. Another specimen of the same, ventral view, natural size, U. S. Nat. Mus. Cat. No. 324451, Station 5866*b*.

PLATE 47.

FIG 1. *Clypeaster gatuni* Jackson, dorsal view. Holotype, slightly reduced, U. S. Nat. Mus. Cat. No. 324453, Station 5662.

PLATE 48.

FIG 1. *Clypeaster gatuni* Jackson, ventral view; same specimen as Plate 47. Holotype, slightly reduced, U. S. Nat. Mus. Cat. No. 324452, Station 5662.

PLATE 49.

FIG 1. *Encope annectans* Jackson, dorsal view, natural size. Holotype, U. S. Nat. Mus. Cat. No. 324454, Station 5846.

2. The same, ventral view.

PLATE 50.

FIG 1. *Encope annectans* Jackson, another specimen, external mould of ventral side seen from above. Natural size, Paratype, U. S. Nat. Mus. Cat. No. 324466, Station 5846.

2. *Schizaster panamensis* Jackson, dorsal view, natural size. Holotype, U. S. Nat. Mus. Cat. No. 324461, Station 7294.

3. The same, ventral view. The dark spot in interambulacrum 5 is a yellow ticket that took black in the photograph.

PLATE 51.

FIG. 1. *Encope platytata* Jackson, dorsal view, natural size. Holotype, U. S. Nat. Mus. Cat. No. 324455, Station 6029*a*.

2. The same, ventral view. The dark spot in interambulacrum 4 of fig. 1 and in interambulacrum 2 of fig. 2 are yellow tickets that took pla in the photographs.

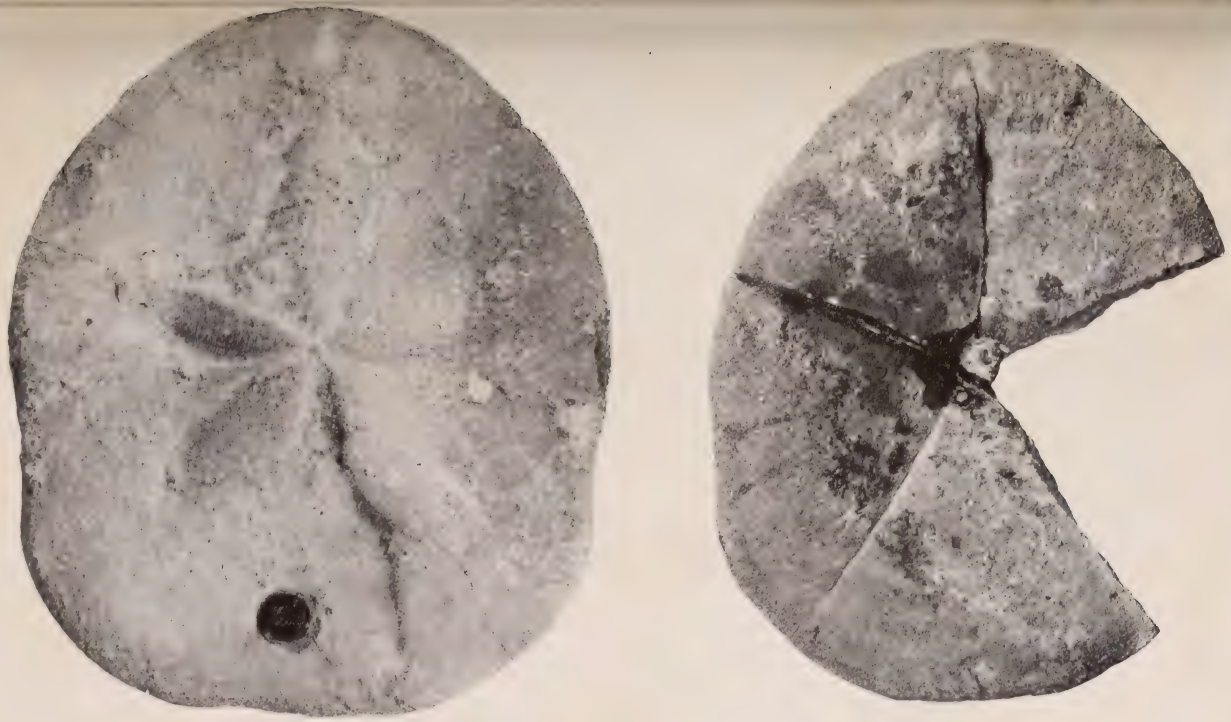
PLATE 52.

FIG. 1. *Encope megatrema* Jackson, dorsal view, natural size. Holotype nat ral size, U. S. Nat. Mus. Cat. No. 324456, Station 6030.

2. *Schizaster cristatus* Jackson, dorsal view, natural size. Ho ty U. S. Nat. Mus. Cat. No. 324460, Station 5505.

3. The same, ventral view.

4. The same, side view.



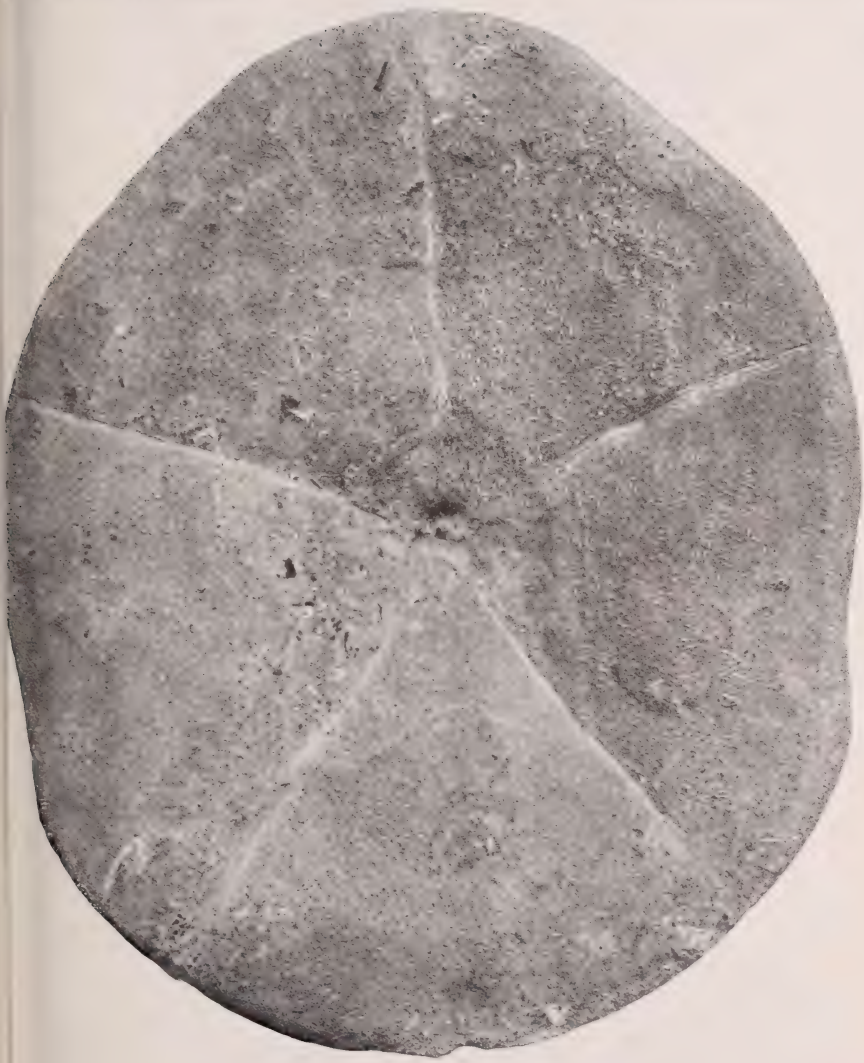
1 2

DORSAL (1) AND VENTRAL VIEWS (2) OF CLYPEASTER LANCEOLATUS.

FOR EXPLANATION OF PLATE SEE PAGE 115

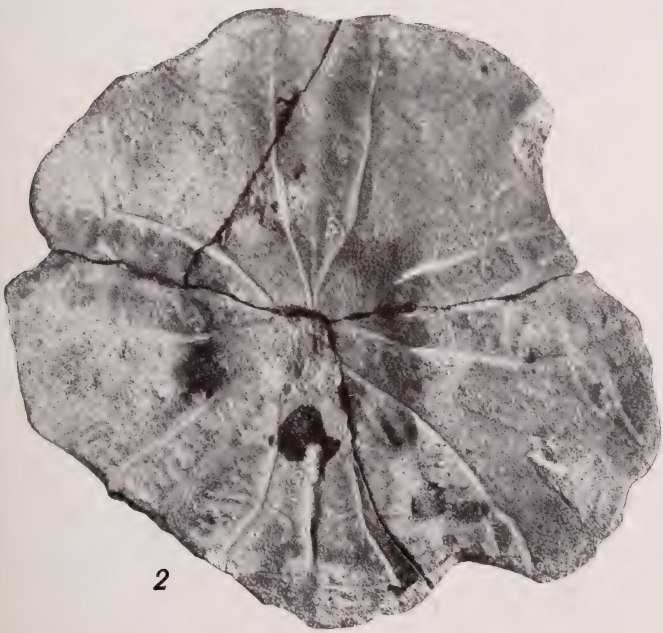
DORSAL VIEW OF CLYPEASTER GATUNI.

FOR EXPLANATION OF PLATE SEE PAGE 115.



VENTRAL VIEW OF CLYPEASTER GATUNI.

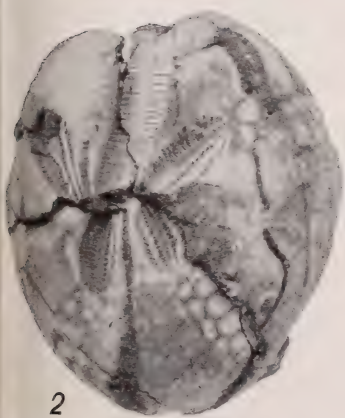
FOR EXPLANATION OF PLATE SEE PAGE 115.



DORSAL (1) AND VENTRAL VIEWS (2) OF ENCOPE ANNECTANS.

FOR EXPLANATION OF PLATE SEE PAGE 115.

1



2

3

MOULD OF VENTRAL SIDE OF ENCOPE ANNECTANS SEEN FROM ABOVE, (2) DORSAL, AND (3) VENTRAL VIEWS OF SCHIZASTER PANAMENSIS.

FOR EXPLANATION OF PLATE SEE PAGE 115.

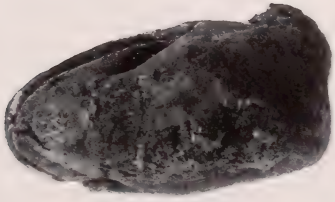
DORSAL VIEW (1) AND VENTRAL VIEW (2) OF ENCOPE PLATYTATA.

FOR EXPLANATION OF PLATE SEE PAGE 116.

1

2

3



4

DORSAL VIEW OF ENCOPE MEGATREMA. DORSAL (2), VENTRAL (3), AND SIDE (4) VIEWS OF SCHIZASTER CRISTATUS.

FOR EXPLANATION OF PLATE SEE PAGE 116

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

)NTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

BRYOZOA OF THE CANAL ZONE AND RELATED AREAS

By FERDINAND CANU
Of Versailles, France
AND
RAY S. BASSLER
Of Washington, District of Columbia

Extract from Bulletin 103, pages 117–122, with Plate 53

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BRYOZOA OF THE CANAL ZONE AND RELATED AREAS.

By FERDINAND CANU
Of Versailles, France
AND
RAY S. BASSLER
Of Washington, District of Columbia.

The following pages contain the descriptions of the few bryozoa at have so far been found in the rocks of the Canal Zone and lated areas. These bryozoa consist of two species from the Em-rador limestone of the Canal Zone collected by Messrs. T. Way-nd Vaughan and D. F. MacDonald and three species from the iocene of Costa Rica collected by D. F. MacDonald. The list of ecies described is as follows:

Ogivalina mutabilis, new species, Emperador limestone, Panama anal Zone.
Holoporella albirostris (Smitt), Emperador limestone, Panama anal Zone.
Cupularia umbellata Defrance, Miocene, Costa Rica.
Cupularia canariensis Busk, Miocene, Costa Rica.
Stichoporina tuberosa, new species, Miocene, Costa Rica.

Order CHEILOSTOMATA.

Group MEMBRANIPORAE.

Genus OGIVALINA Canu and Bassler.

OGIVALINA MUTABILIS, new species.

Plate 53, fig. 1.

The zoarium is incrusting. The zoœcia are elongated, oval, dis-act, separated by a deep furrow; the mural rim is thin, smooth, unded; there is often a small gymnocyst. The opesium is very rge, irregular, more often oval. The ovicell is endozoœcial, small,

little convex. Sometimes there is a small interzoœcial fusiform avicularium (?).

Measurements.—Opesium $\begin{cases} ho = 0.60–0.70 \text{ mm} \\ lo = 0.30–0.45 \text{ mm} \end{cases}$

Zoœcium $\begin{cases} Lz = 0.75–0.95 \text{ mm} \\ lz = 0.50–0.70 \text{ mm} \end{cases}$

The great irregularity of form and zoœcial dimensions of this species justifies its name. There are some variations which recall those of *Membranipora irregularis* Manzoni, 1875[1] which possesses a mural rim enlarged at the base and also some large interzoœcial avicularia.

The present species differs from the splendid *Ogivalina eximia* Canu and Bassler from the Middle Jacksonian of North and South Carolina in its smaller dimensions, in the absence of cryptocyst, and in the presence of a gymnocyst. The avicularium (?) is identical in form and position.

Occurrence.—Emperador limestone, old quarry, one-third mile north of west of Empire, Panama Canal Zone. D. F. MacDonald and T. Wayland Vaughan, collectors, 1914, Station No. 6016.

Southwest side Crocus Bay Hill, Anguilla, Leeward Islands. T. Wayland Vaughan, collector, 1914, Loc. No. 6893.

Holotype.—Cat. No. 65039, U.S.N.M.

Family OPESIULIDAE Jullien.

Genus CUPULARIA Lamouroux.

CUPULARIA UMBELLATA Defrance, 1823.

Plate 53, figs. 2–4.

1908. *Cupularia umbellata* Canu, Iconographie des Bryozoaires fossiles de l'Argentine, Anales del Museo Nacional de Buenos Aires, vol. 17, p. 275, pl. 5, figs. 4, 5. (See for complete bibliography.)

1909. *Cupularia umbellata* Canu, Bryozoaires fossiles du Sud-Ouest de la France, Bulletin de la Société Geologique de France ser. 4, vol. 9, pp. 448, 454, pl. 16, figs. 16, 17. (Regional bibliography.)

1909. *Cupularia lowei* Norman, On the Polyzoa of Madeira, Journ. Linnean Soc., vol. 30, p. 290, pl. 37, figs. 7–12.

1913. *Cupularia umbellata* Canu, Étude comparée des Bryozoaires helvetiens de l'Égypte avec les Bryozoaires vivants de la Mediterranée et de la Mer Rouge, Mem. a l'institut Egyptien, vol. 6, fasc. 3, p. 2.

1913. *Cupularia umbellata* Canu, Cont. a l'etude des Bryozoaires fossiles, pt. 5, p. 125; pt. 7, p. 126; pt. 12, p. 127; Bulletin Soc. Geol. France (IV, XIII).

1914. *Cupularia lowei* Osburn, The Bryozoa of the Tortugas Islands, Florida. Publication No. 182, of the Carnegie Institution of Washington, p. 194.

[1] Briozoi del pliocene antico di Castrocaro, Bologna, 1875, p. 10, pl. 1, figs. 5, 8.

The fossils which are identified as above are rather well preserved ıd their determination is easy. The pores of the hydrostatic zoœcia 'e not radicular. We are ignorant as to why Norman, who is a 'eat lover of archaic names, has not preserved the name of Defrance. he figures published by this author and by d'Orbigny are excellent ıd leave no doubt as to the identity of the two species.

Occurrence.—Miocene, Banana River, Costa Rica. D. F. Macɔnald, collector, 1911. Bowden marl, Bowden, Jamaica.

This species is almost always associated with *C. canariensis* Busk. .ke the latter, it commences in the Alum Bluff formation and conıues in the higher Miocene and Pliocene deposits of the United ates.

Geological distribution.—Aquitanian of Italy (Seguenza, Nevii), of Bordeaux (Canu). Burdigalian of Italy (Seguenza, Canu), Bordeaux (Canu). Helvetian of Italy (Seguenza), of Touraine anu), of Bordeaux (Canu), of Maryland (Ulrich), of Egypt anu). Tortonian of Provence (Canu), of Italy (Seguenza). aisancian of England (Busk), of Italy (Manzoni). Astian of aly (Neviani, Canu), of Provence (Canu). Sicilian of Italy eviani). Quaternary of Italy (Seguenza), of England (Canu).

Habitat.—Mediterranean. Atlantic to the Canary Islands, and orida. It is common in the Gulf of Gascony in the Miocene; it s now disappeared from it.

It has been dredged at a depth of 11 to 48 meters in America and ɔm 81 to 113 meters in Madeira.

CUPULARIA CANARIENSIS Busk.

Plate 53, figs. 5–7.

1908. *Cupularia canariensis* Canu, Iconographie des Bryozoaires fossiles de l'Argentine, Anales del Musee Nacional de Buenos Aires, vol. 17 (ser. 3, vol. 10), pt. 1, p. 275, pl. 5, figs. 8, 9, 10. (See for complete bibliography.)

1909. *Cupularia guineensis* Norman, The Polyzoa of Madeira and neighboring islands, Linnean Society's Journal, Zool., vol. 30 (July), p. 289, pl. 37, figs. 2–6.

1914. *Cupularia guineensis* Osburn, The Bryozoa of the Tortugas Islands, Florida, Publication No. 182, of the Carnegie Institute of Washington, p. 194.

The beautiful figure published by Busk in 1859, has led all paleontogists to use the specific term *canariensis*, especially since the same thor distinguished this species from *Cupularia guineensis* Busk, 54. For a half century, it was therefore employed by Busk, Waters, anzoni, Van den Brock, Neviani, Seguenza, De Angelis, and Canu. Now it appears established that Busk's two species are identical orman, Osburn). We do not believe it necessary to change the

names of these species as the latter authors have done since h author of each is the same. A simple question of date ought o alter all the literature of this species which although it has n e been entirely published is nevertheless quite important.

Our American specimens are well preserved.

Occurrence.—Miocene, Banana River, Costa Rica. D. F. Macl n ald, collector, 1911. Bowden marl at Bowden, Jamaica.

The earliest occurrence of this species in the United States is ir h Alum Bluff formation, but it is found also at many other horizor o the Miocene and Pliocene.

Geological distribution.—Burdigalian of Bordeaux (Colle or Canu). Helvetian of France (Canu) of Spain (De Angelis). r tonian of Austria-Hungary (Reuss), of Italy (Seguenza). P is ancian of Italy (Manzoni), of England (Busk), of Spain (De n gelis), of Algeria (Canu). Astian of Italy (Neviani, Canu). S il ian of Rhodes (Manzoni), of Italy (Neviani). Quaternary of I ly (Neviani), of Argentina (Canu). Miocene of Australia? (Wat s).

Family CELLEPORIDAE Busk.

Genus HOLOPORELLA Waters.

HOLOPORELLA ALBIROSTRIS (Smitt).

Plate 53, fig. 8.

1873. *Discopora albirostris* SMITT, Floridan Bryozoa, pt. 2, Kongl. Sv ska Vetenskaps-Akademiens Handlingar, vol. 11, No. 4, p. 70, pl. 12 gs. 233–239.

1889. *Cellepora albirostris* JELLY, A Synonymic Catalogue of the R ent Marine Bryozoa, p. 45. (See for complete bibliography.)

1914. *Holoporella albirostris* OSBURN, Bryozoa of Tortugas Islands, ub. 182, Carnegie Institution, p. 215.

Of the two specimens of this species which have been collect at Panama and at Anguilla one corresponds to Smitt's figure 237 nd the other to figure 238.

Occurrence.—Rare in the Emperador limestone at the old q r y one-third mile north of west of Empire, Panama Canal Zone, I F. MacDonald and T. Wayland Vaughan, collectors, 1911 (St ion No. 6106). Also rare along the southwest side of Crocus Bay, n- guilla, Leeward Islands, Dr. T. Wayland Vaughan, collector, 14, Loc. No. 6894.

Geological distribution.—Miocene of Australia and New Zea nd (Waters). Habitat. Atlantic off Florida. Pacific off Aust lia. Specimens have been dredged off Australia to a depth of 121 m rs. Smitt in Florida has discovered them between 40 and 56 meters out Osburn states that it abounds at a depth of 24 meters.

Family CONESCHARELLINIDAE Levinsen.

Genus STICHOPORINA Stoliczka.

STICHOPORINA TUBEROSA, new species.

Plate 53, figs. 9–12.

The zoarium is free, conical, hollow with very thick walls. The peristome is salient, ornamented with small tuberosities; it bears one or two small elliptical avicularia with bar or denticles. The ovicell is large, somewhat salient, convex; it is hyperstomial and always closed by the operculum. On the lower face, there are large pores surrounded by very small ones.

Measurements.—Apertura $\begin{cases} ha = 0.15 \text{ mm.} \\ la = 0.09 \text{ mm.} \end{cases}$

This is a very elegant species characterized by its peristomial tubercles. The ancestrula is visible only in the interior of the zoarium; it is covered exteriorly by the first zoœcia. All the zoœcia are separated from each other by small canals which appear to end in the large, inferior pores.

This species must not be confounded with *Mamillopora cupula* Smitt, 1872. It differs from it in its ovicell which is not bilobate and in its ovarian zoœcia which are not larger than the others.

Occurrence.—Miocene, Banana River, Costa Rica, D. F. McDonald, collector, 1911.

Cotypes.—Cat. No. 65040, U.S.N.M.

EXPLANATION OF PLATE 53.

Ogivalina mutabilis, new species.

Fig. 1. The type-specimen, × 20, with large irregular opesia, small ovicell, small gymnocyst and one zœcium with a fusiform avicularium.
Emperador limestone, Crocus Bay Hill, Anguilla.

Cupularia umbellata Defrance.

Fig. 2. Two zoaria, natural size.
3. Celluliferous convex surface, × 20.
4. Concave surface, × 20.
Miocene, Banana River, Costa Rica.

Cupularia canariensis Busk.

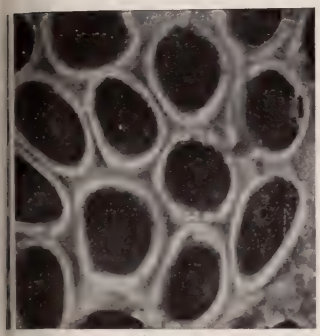
Fig. 5. Two zoaria, natural size.
6. Celluliferous convex surface, × 20.
7. Concave surface, × 20.
Miocene, Banana River, Costa Rica.

Holoporella albirostris (Smitt).

FIG. 8. Several zoœcia much enlarged (after Smitt).
Recent, Gulf of Mexico.

Stichoporina tuberosa, new species.

FIG. 9. Two zoaria, natural size.
10, 11. Two views × 20, of the convex, celluliferous side.
12. Photograph of the concave side, × 20.
Miocene, Banana River, Costa Rica.



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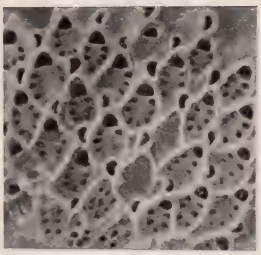

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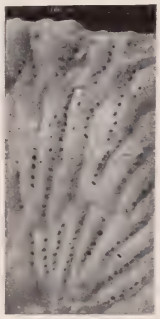

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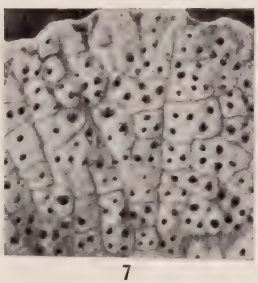

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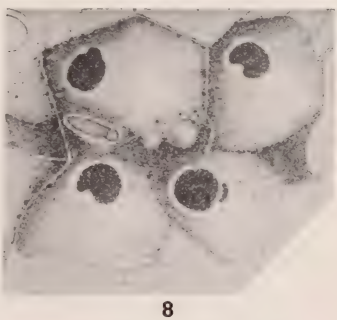

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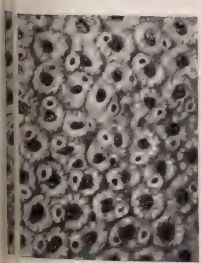

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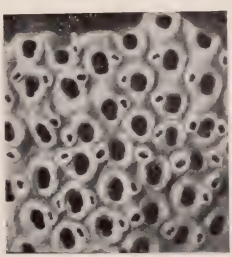

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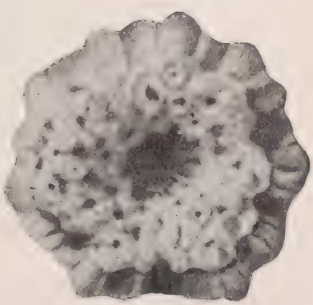

12

BRYOZOA OF THE PANAMA CANAL ZONE AND RELATED AREAS.

FOR EXPLANATION OF PLATE SEE PAGES 121, 122.

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[Synonyms are in italics.]

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

ONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

DECAPOD CRUSTACEANS FROM THE PANAMA REGION

By MARY J. RATHBUN
Associate in Zoology, United States National Museum

Extract from Bulletin 103, pages 123–184, with Plates 54–66

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1918

DECAPOD CRUSTACEANS FROM THE PANAMA REGION.

By Mary J. Rathbun,

Associate in Zoology, United States National Museum.

INTRODUCTION.

Fifty-eight species of Decapods are enumerated from the collections examined by the author. Three species described by other authors are inserted in systematic order, thus making the list complete to date for the Panama region. All the available material in the United States National Museum from Panama and Costa Rica is included; it ranges in age from the Oligocene (Culebra formation) to the Pleistocene.

In the list of stations and the table of distribution the data relating to Cirripedia from Dr. H. A. Pilsbry's report are included for convenience of reference.

The literature on Panama Tertiary Decapods is so scanty that it is not surprising that nearly all of the forms now examined prove to be new. Six species previously described from living forms are here recorded from the Pleistocene (4 species) or the Pliocene (2 species). Thirty-nine species are described as new, three are types of new genera, and one of these is the type of a new family, the Gaillardiidae. This is an extremely large and massive crab and combines the characters of the well-known Recent families, the Cancridae and the Portunidae. The most remarkable occurrence is that of a member of the Hexapodinae, that subfamily of the Goneplacidae in which the legs of the last pair are wanting. This is a small group of Recent forms containing 5 genera and 8 species and is strictly Indo-Pacific. The species from the Oligocene of Panama is the first one observed in a fossil state. Many other genera dealt with in this report have never before been found fossil. Such are *Pachycheles*, *Petrolisthes*, *Pilumnus*, *Hepatus*, *Mursia*, *Leucosilia*, *Euphylax*, *Heteractaea*, *Eurycarcinus*, *Euryplax*, and *Cardisoma*.

As in all large collections of fossil crustaceans there are a number of fragments whose position is problematic. Some of these can be determined as to genera, others as to family only.

LITERATURE ON TERTIARY DECAPODS OF PANAMA.

BOUVIER, E. L. Calappa Zurcheri, Crabe nouveau des terrains t
cènes de Panama. Bull. Mus. Hist. Nat. Paris, vol. 5, 1899,
189–192, 1 text-fig.

Calappa zurcheri is not represented in the United States Geological Su
collections.

TOULA, FRANZ. Die jungtertiäre Fauna von Gatun am Pana
kanal. II. Teil. Jahrbuch der k. k. Geolog. Reichsans
Wien, vol. 61, 1911, pp. 487–530 (1–44), pls. 30, 31 (1, 2).

The hermit-crab (*Petrochirus*) noted and figured by Toula (p. 511, pl. 3
13) I have ventured to describe as a new species, combining as it does the
acters of the two nearly related Recent species which inhabit opposite sid
the continent. The "Krabbenscheren" of Toula (p. 512, pl. 30, fig. 14) ar
scribed below as a species of *Callianassa, C. toulai.*

BROWN, AMOS P., and PILSBRY, HENRY A. Fauna of the Gatun
mation, Isthmus of Panama. II. Proc. Acad. Nat. Sci. Ph
delphia, vol. 64, Dec. 1912 (publ. Jan. 30, 1913), pp. 500–519,
22–26.

The author is indebted to Dr. H. A. Pilsbry for the loan of the specime
Callianassa in the collection of the Philadelphia Academy of Natural Sci
which were described by Brown and Pilsbry. They have been critically
pared with those collected by the United States Geological Survey.

LIST OF STATIONS FROM WHICH MATERIAL HAS BEEN EXAMI
ARRANGED FROM THE EARLIEST TO THE LATEST, WITH
SPECIES FOUND AT EACH.

Station 6012a.[1]—Panama Canal Zone. One-quarter mile sout
Empire Bridge. From lower dark clay beneath lower conglome
Culebra formation (lower part). Oligocene series. Collec
D. F. MacDonald and T. W. Vaughan; 1911. *Balanus* (*Hes
balanus?*), species. *Callianassa lacunosa* Rathbun.

Station 6010.—Panama Canal Zone. Near Panama Canal St
"1910," north of Pedro Miguel locks. From dark clay. Cu
formation (lower part). Oligocene series. Collectors, D. F.
Donald and T. W. Vaughan; 1911. *Mursia obscura* Rathbun.

*Specimens in Museum, Academy of Natural Sciences, Phil
phia.*—Panama Canal Zone. Las Cascadas section, Gaillard
Lignitic layers about 65 feet below the base of *Pecten* bed at T
N. Culebra formation (central part). Oligocene series. Coll
Prof. William B. Scott; 1911. *Callianassa scotti* Brown and
bry. *Callianassa spinulosa* Rathbun. *Callianassa quadrata*
bun.

[1] The station numbers refer to the station book of Cenozoic Invertebrate fossils
United States National Museum.

Station 6019b.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. Four feet of dark, stratified tuff and clay immediately overlying the lower limestone bed. Culebra formation (upper part). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Callianassa scotti* Brown and Pilsbry. *Callinectes*, species, *Xanthopeus*, species.

Specimen in Museum, Academy of Natural Sciences, Philadelphia.—Costa Rica. Probably Culebra formation. Oligocene series; labeled "Miocene." Collector, W. M. Gabb. *Callianassa scotti* Brown and Pilsbry.

Station 6019c.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. Lower part of lime-cemented soft gray to olive-colored limestone, with central parting of dark clay. The first hard, limy sandstone bed above the lower limestone and just above 6019*b*. Culebra formation (upper part). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Callianassa vaughani* Rathbun (probably). *Callianassa ?*, species. *Hepatus*, species.

Station 6019e.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. Third hard sandstone bed from bottom. Culebra formation (upper part). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Callianassa stridens* Rathbun.

Station 6012c.—Panama Canal Zone. Gaillard Cut. Top part of clay sandstone below upper conglomerate, near foot of stairs. Culebra formation (upper part). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. Natantia, family, genus, and species indeterminable. *Callianassa*, species. *Callinectes*, species. *Euryplax culebrensis* Rathbun.

Station 6020a.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. Lowest fossiliferous bed. Third bed below lowest limestone beds separated by rows of nodules. Culebra formation (lower part of upper half). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Balanus* (*Hesperibalanus?*), sp. *Axius reticulatus* Rathbun. *Callianassa ovalis* Rathbun. *Callianassa elongata* Rathbun. *Callianassa crassimana* Rathbun. *Callianassa spinulosa* Rathbun. *Callianassa quadrata* Rathbun. *Callianassa abbreviata* Rathbun. *Callianassa magna* Rathbun. *Goniochele ? armata* Rathbun. *Calappella quadrispina* Rathbun. *Callinectes reticulatus* Rathbun. *Thaumastoplax prima* Rathbun. Brachyrhyncha, family, genus, and two species indeterminable.

Station 6025.—Panama Canal Zone. About 200 yards south of southern end of switch at Bohio Ridge station, relocated line Panama Railroad. Foraminiferal marl and coarse sandstone. Culebra formation (upper part). Oligocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Carpilius*, species.

Station 6019g.—Panama Canal Zone. Las Cascadas section, Gillard Cut. Fifth or topmost limestone. Emperador limestone. Miocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Macrobrachium*, species. *Callianassa tenuis* Rathbun. *Mursia macdonaldi* Rathbun. *Parthenope panamensis* Rathbun.

Station 6003.—Panama Canal Zone. Gatun section A, bed A (bottom of section). Gatun formation (lower part). Miocene series. Collector, D. F. MacDonald. *Callianassa crassa* Rathbun.

Station 6029a.—Panama Canal Zone. One-fourth to one-half mile beyond Camp Cotton toward Monte Lirio. From lowest horizon in big cut. Gatun formation (lower part). Miocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Callianassa vaughani* Rathbun.

Station 6033b.—Panama Canal Zone. Gatun section. Upper part of lowest bed. Gatun formation. Miocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Lepas injudicata* Pilsbry. ? *Gatunia proavita* Rathbun.

Station 6030.—Panama Canal Zone. One and one-half to 2 miles beyond Camp Cotton toward Monte Lirio. From 85-foot cut on north side of big swamp on relocated line, P. R. R. Gatun formation. Miocene series. Collectors, D. F. MacDonald and T. W. Vaughan; 1911. *Balanus concavus rariseptatus* Pilsbry. *Callianassa vaughani* Rathbun *Gatunia proavita* Rathbun.

Station 5900.—Panama Canal Zone. Gatun Locks. Gatun formation. Miocene series. Collector, D. F. MacDonald; May, 1911. *Gatunia proavita* Rathbun.

Catalogue No. 113706, U.S.N.M.—Panama Canal Zone. Near Gatun. Gatun formation (?). Miocene series. Labeled "Miocene." Collector, Rev. J. Rowell. *Gatunia proavita* Rathbun.

Station 5659.—Panama Canal Zone. Near Gatun Dam. Gatun formation. Miocene series. Collector, one of the workmen; shipped by D. F. MacDonald; 1911. *Gatunia proavita* Rathbun.

Catalogue No. 135218, U.S.N.M.—Panama Canal Zone. Gatun beds. Gatun formation. Miocene series. Collector, R. T. Hill. *Callianassa hilli* Rathbun.

Catalogue No. 135219, U.S.N.M.—Panama Canal Zone. Gatun beds. Gatun formation. Miocene series. Collector, R. T. Hill. *Mursilia ecristata* Rathbun.

Station 5882k.—Costa Rica. Banana River; tenth fossiliferous zone below the uppermost one of the section. Probably equivalent to Gatun formation. Miocene series. Collector, D. F. MacDonald; 1911. *Euphylax fortis* Rathbun.

Station 5882j.—Costa Rica. Banana River; ninth fossiliferous zone below the uppermost one of the section. Probably equivalent to Gatun formation. Miocene series. Collector, D. F. MacDonald; 1911. *Euphylax callinectias* Rathbun.

Station 5882i.—Costa Rica. Banana River; eighth fossiliferous ne below the uppermost one of the section. Probably equivalent Gatun formation. Miocene series. Collector, D. F. MacDonald; 11. *Callinectes declivis* Rathbun.

Station 5882h.—Costa Rica. Banana River; seventh fossiliferous ne below the uppermost one of the section. Probably equivalent to tun formation. Miocene series. Collector, D. F. MacDonald; 11. *Leucosilia bananensis* Rathbun.

Station 5882g.—Costa Rica. Banana River; sixth fossiliferous ne below the uppermost one of the section. Probably equivalent to tun formation. Miocene series. Collector, D. F. MacDonald; 11. *Leucosilia bananensis* Rathbun.

Station 5882f.—Costa Rica. Banana River; fifth fossiliferous ne below the uppermost one of the section. Probably equivalent to tun formation. Miocene series. Collector, D. F. MacDonald; 11. *Leucosilia bananensis* Rathbun.

Catalogue No. 324287, U.S.N.M.—Costa Rica. Moin Hill, near mon. Probably equivalent to Gatun formation. Miocene series. llector, H. Pittier. *Callianassa moinensis* Rathbun.

Station 5884d.—Costa Rica. Moin Hill; third fossiliferous zone low the uppermost; just above level of the rails in railway cut. obably equivalent to Gatun formation. Miocene series. Col- tor, D. F. MacDonald; 1911. *Callianassa moinensis* Rathbun.

Station 5906a.—Panama Canal Zone. Chagres River, 50 to 75 feet low those of (17*c*) "5905" in lighter colored limestone according incomplete evidence. Pliocene series. Collector, D. F. Mac- nald; May, 1911. *Balanus glyptopoma* Pilsbry.

Station 5903.—Panama Canal Zone. From across Chagres River d probably 220 to 225 feet above level of river, top of hill opposite hajuela. Gray tufaceous limestone. Pliocene series. Collector, F. MacDonald; May, 1911. *Balanus glyptopoma* Pilsbry.

Station 4269.—Costa Rica. City of Port Limon. Port Limon rmation. Pliocene series. Collector, Dr. L. A. Wailes. *Pa- ycheles latus* Rathbun. *Petrolisthes avitus* Rathbun. *Calappa staricana* Rathbun. *Heteractaea lunata* (Milne Edwards and icas). *Cardisoma guanhumi* Latreille.

Station 5886.—Mexico. From the Sayula District of Chiapas. n the Arroyo Chapapoapam. Pliocene series. Collectors, Dr. W. Hayes and others, 1911. *Balanus glyptopoma* Pilsbry.

Station 6038.—Panama Canal Zone. From black mud from lower d of Gatun Locks. Pleistocene series. Collector, D. F. MacDon- d; 1911. *Balanus eburneus* Gould.

Station 5867.—Panama Canal Zone. From dark mud forma on, about 10 feet above present sea level, near lower end of Gatun Locks. Pleistocene series. Collector, D. F. MacDonald; April, 1911. *Balanus eburneus* Gould.

Station 5868.—Panama Canal Zone. From Mount Hope. Swamp ditch. Black mud formation. Pleistocene series. Collector, D. F. MacDonald; April, 1911. *Balanus eburneus* Gould.

Station 5850.—Panama Canal Zone. Near Mount Hope in ditch through swampy ground. About one-fourth mile from present sea beach and about 6 to 8 feet above high tide. Pleistocene series. Collector, D. F. MacDonald; April, 1911. *Macrobrachium?*, species. *Nephrops costatus* Rathbun. *Nephrops*, species. *Axius?*, species. *Hepatus chiliensis* Milne Edwards. *Calappa flammea* (Herbst). *Leucosilia jurinei* (Saussure). Leucosiidae, genus and species indeterminable. *Arenaeus*, species. *Panopeus antepurpureus* Rathbun. *Panopeus tridentatus* Rathbun. *Eurytium crenulatum* Rathbun. *Uca macrodactylus* (Milne Edwards and Lucas). *Parthenope pliocenica* Rathbun.

In the following table the Cirripedia (see pp. 185–188) are included with the Decapoda. The letter "n" after a name in the first column indicates a new species or a new genus. The numerical headings refer to the same stations as in the above list but are arranged serially instead of chronologically.

Distribution of Panama Crustaceans.	4269.	5659.	5850.	5867.	5868.	5882f.	5882g.	5882h.	5882i.	5882j.	5882k.	5884d.	5886.	5900.	5903.	5906a.	6003.	6010.	6012a.	6012c.	6019b.	6019c.	6019e.	6019g.	6020a.	6025.	6029a.	6030.	6033b.	6038.	18. R. T. Hill.	Cat. No. 113706.	W. B. Scott.	H. Pittier.	W. M. Gabb.	Previously record
Balanus eburneus Gould				×	×																									×						
glyptopoma Pilsbry													×		×	×												×								
concavus rariseptatus Pilsbry, n.																																				
(*Hesperibalanus?*), sp																			×						×											
Lepas injudicata Pilsbry, n																													×							
Natantia, family, genus, and species indet																				×																
Macrobrachium, sp																								×												
?, sp			×																																	
Nephrops costatus, n			×																																	
sp			×																																	
Pachycheles latus, n	×																																			
Petrolisthes avitus, n	×																																			
Axius reticulatus, n																									×											
?, sp			×																																	
Callianassa ovalis, n																									×											
lacunosa, n																			×																	
elongata, n																									×											
scotti Brown and Pilsbry																					×												×		×	
crassimana, n																									×											
moinensis, n												×																						×		
spinulosa, n																									×								×			
tenuis, n																								×												
quadrata, n																									×								×			
toulai, n																																				×
abbreviata, n																									×											
hilli, n																															×					
vaughani, n																						×					×	×								
stridens, n																							×													
magna, n																									×											
crassa, n																	×																			
sp																				×																
? sp																						×														
Petrochirus bouvieri, n																																				×
Goniochele? armata, n																									×											
Hepatus chiliensis Milne Edwards			×																																	
sp																						×														

Distribution of Panama Crustaceans (continued).

	4269.	5659.	5850.	5867.	5865.	5882f.	5882g.	5882h.	5883i.	5882j.	5882k.	5884d.	5886.	5900.	5903.	5906a.	3.	6010.	6012a.	6012c.	6019b.	6019c.	6019d.	6019g.	6020a.	6025.	6029a.	6030.	6033b.	6038.	18, R. T. Hill.	Cat. No. 113706.	W. R. Scott.	H. Pittier.	W. M. Gabb.	Previously recorded.
Calappa costaricana, n.	×																																			
flammea (Herbst)			×																																	
zwcheri Bouvier																																				
Calappella, n., *quadrispina*, n.																									×											
Mursia macdonaldi, n.																																				
obscura, n.																		×																		
Mursilia, n., *cristata*, n.			×																												×					
Leucosilia jurinei (Saussure)						×	×																													
benanensis, n.			×			×			!																											
Leucosiidae?, genus and species indet.									×																											
Callinectes declivis, n.																									×											
reticulatus, n.																					×															
sp.																				×																
sp.																																				
Arenaeus, sp.										×																										
Euphylax cultrirectus, n.			×								×																									
fortis, n.																																				
Gatunia, n., *proavita*, n.		×												×																						
Carpilius, sp.																																				
Hderactaea lunata (Milne Edwards and Lucas)	×																																			
Panopeus antillensis, n.			×																																	
tridentatus, n.			×																																	
sp.																																				
Eurytium crenulatum, n.			×																																	
Eurytium culebrensis, n.																																				
Thaumastoplax prima, n.																									×											
Cardisoma guanhumi Latreille																										×										
Uca macrodactylus (Milne Edwards and Lucas)			×																																	
Brachyrhynchi, family, genus, and species indet.																																				
Brachyrhynchi, family, genus, and species indet.																																				
Parthenope panamensis, n.																																				
pleistocenica, n.			×																																	

DESCRIPTIONS OF SPECIES.

Subclass MALACOSTRACA.

Order DECAPODA.

Suborder NATANTIA.

Family, genus, and species indeterminable.

Plate 57, fig. 1.

Locality.—Panama Canal Zone. Top part of limy sandstone below per conglomerate, near foot of stairs, Gaillard Cut. Upper part Culebra formation. Oligocene series. D. F. MacDonald and W. Vaughan, collectors. 1911. Station 6012*c*. Cat. No. 324267, S.N.M.

Material.—One specimen showing three segments from the pleon a shrimp. Pleon compressed laterally. Each of the two overlapping segments has the posterior angle produced backward in a rounded lobe of moderate size.

Family PALAEMONIDAE.

MACROBRACHIUM, species.

Plate 57, figs. 4 and 5.

Locality.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. From fifth or topmost limestone. Emperador limestone. Oligocene series. D. F. MacDonald and T. W. Vaughan, collectors, 1911. Station 6019*g*. Cat. No. 324256, U.S.N.M.

Material.—One propodus of left cheliped, minus finger. Slightly compressed, subcylindrical. Some of the outer crust is lacking, but in general, the segment widens rapidly for the proximal two-fifths, then widens gradually at the middle, but not at all in the distal two-fifths. There is no shallow sinus in the lower margin behind the finger, as in *M. jamaicense*,[1] *M. acanthurus panamense*[2] and others; neither is the palm like that of *M. mexicanum*,[3] which is not at all convex below, and has subparallel margins.

The specimen resembles *Macrobrachium* more than it does any marine genus now existing in Panamian waters.

---

[1] *Cancer* (*Astacus*) *jamaicensis* Herbst, Natur. Krabben u. Krebse, vol. 2, 1792, p. 57, 27, fig. 2.

Rathbun, in Smithson. Misc. Coll., vol. 59, No. 13, 1912, p. 1.

[3] *Palaemon mexicanus* Saussure, Mém. Soc. Phys. Hist. Nat. Genève, vol. 14, 1858, 68 [52], pl. 4, figs. 27, 27*a*.

Measurements.—Length of palm, 13 mm.; width, 4.3 mm.; thickness, 3.7 mm.

MACROBRACHIUM?, species.

Plate 57, fig. 9.

Locality.—Panama Canal Zone. From near Mount Hope in ditch through swampy ground. About one-quarter mile from present sea beach, 6 to 8 feet above high tide. Pleistocene series. D. F. MacDonald, collector. April, 1911. Station 5850. Cat. No. 32418, U.S.N.M.

Material.—One segment (perhaps the carpus) of the second or large pair of chelipeds, probably the left one. Subcylindrical, enlarging gradually to the distal end, slightly curved, a longitudinal row of 5 low conical spines irregularly spaced.

Measurements.—Length, 9.5 mm.; diameter, 1.7 mm.

Suborder REPTANTIA.

Tribe ASTACURA.

Family HOMARIDAE.

NEPHROPS COSTATUS, new species.

Plate 57, figs. 13–17.

Type-locality.—Panama Canal Zone. From near Mount Hope in ditch through swampy ground. About one-quarter mile from present sea beach, 6 to 8 feet above high tide. Pleistocene series. D. F. MacDonald, collector. April, 1911. Station 5850.

Types.—Cat. No. 324246, U.S.N.M.

Material.—Three dactyli of left cheliped, one of which is fairly complete and is taken as the holotype; the other specimens show only the distal half or two-thirds. A fourth specimen (distal half only) represents a fixed finger perhaps and if so belongs on the left side.

Holotype.—Length 9.5 mm. In dorsal view the inner or right margin is sinuous, the tip curved strongly inward; viewed from the inside, both edges are sinuous, curving downward toward the tip. Upper and lower surfaces a little flattened. Five longitudinal costae, 2 dorsal, 2 ventral, 1 inner; each costa marked by a line of fine granules, with a row of punctae adjacent. On the proximal half

re is some intercostal granulation. Prehensile edge armed with
teeth and divided into 3 sinuses separated by 2 large teeth; the
al of these has its distal edge normal and its proximal edge
ique to the margin of the dactylus; the top of the other large tooth
roken off; the terminal bay has a somewhat enlarged, but still
ll, tooth at its middle.

aratypes.—(*a*) Distal half of dactylus, but with small tip lack-
, same width as holotype; terminal sinus same length but more
ved, so that the distal border of the boundary tooth is shorter;
ldle sinus half as long, nondentate, next boundary tooth broader
n in holotype.

b) Dactylus with proximal end lacking, same width as holotype,
ae more rounded, terminal sinus a little shorter, boundary tooth
h end missing, enlarged middle tooth better developed than in
otype, pointing obliquely distad; middle sinus longer, boundary
h broken.

c) Propodal (?) finger broader than the others, showing one
is nearly equal to 2 sinuses of the holotype and limited by a large
h with nearly equal sides.

have placed this species in *Nephrops* on account of the ribbed
gers irregularly toothed. The variations in the dactyl may repre-
t either individual or sexual variation.

NEPHROPS, species.

Plate 57, figs. 25 and 26.

ocality.—Panama Canal Zone. From near Mount Hope in ditch
ough swampy ground. About one-quarter mile from present sea
ch, 6 to 8 feet above high tide. Pleistocene series. D. F. Mac-
nald, collector. April, 1911. Station 5850. Cat. No. 324249,
.N.M.

aterial.—Dactylus of right cheliped, 12 mm. long; distal half
derately curved toward the propodal finger, but the whole finger
ngly curved downward; 6 strong, longitudinal costae, 3 dorsal,
arginal, 2 ventral; about 9 lines of punctae; the prehensile teeth,
in all, are larger and more projecting in that two-fifths of the
rgin just posterior to the middle.

fter the above description was written the proximal half of the
imen was accidentally crushed and destroyed.

lthough the dactylus is much more curved than in any species of
hrops, yet its ornamentation is so similar to that of the preced-
species, *N. costatus*, that it is referred to the same genus.

Tribe ANOMURA.

Superfamily GALATHEIDEA.

Family PORCELLANIDAE.

PACHYCHELES LATUS, new species.

Plate 57, figs. 21–23.

Type-locality.—Costa Rica; Port Limon. Pliocene series. L. A. Wailes, collector. Station 4269. Holotype, left manus v propodal finger; inner proximal corner of manus broken off. P type, left manus, with both fingers; proximal portion of ma broken off.

Type.—Cat. No. 324264, U.S.N.M.

Measurements.—Width of palm, 4.6 mm.; length of same to si 5.1 mm.; length to end of finger, 6.7 mm.; greatest thickness, 2.3 m

Holotype.—Outer and inner margins thick and strongly cur in dorsal view; upper surface covered with granules crowded to gether and of varying size; the granules are continued on the o surface and a little way on the under surface; they are then repla by squamiform granules and short rugae which are continued o the inner surface. There are no marginal lines indicated. At t distal end, the width from the articulating condyle to the inner a is nearly as great as to the outer margin. The fixed finger is sl and stout, width subequal to length; a bit of the tip is, howe missing; a low tooth occupies the greater part of the basal hal the prehensile edge.

Paratype.—Smaller than the holotype and much worn so that granulation is not well marked. Tooth at base of immovable fi minute. Movable finger very short and broad, granulate, wit basal prehensile tooth, its surface granulate.

In general shape and granulation, this form resembles the ma of the Recent *P. grossimanus* (Guérin) from Peru and Chile, bu the latter the outer margin is paved with larger granules formi definite edge, and the propodal finger is longer and more curved.

PETROLISTHES AVITUS, new species.

Plate 57, figs. 18–20.

Type-locality.—Costa Rica; Port Limon. Pliocene series. L. A. Wailes, collector. Station 4269.

Type.—Cat. No. 324266, U.S.N.M.

Holotype.—Palm of left cheliped, showing the greater part of upper and lower surfaces including the inner margin and the di

culating edge of the lower surface. Outer edge, proximal end, finger missing. Upper surface covered with coarse granulated ne of very different lengths, varying from 1 to 10 or 12 granules, arranged obliquely longitudinally. Lower surface covered with ed, wavy and punctate striae starting almost at right angles with inner margin, curving slightly forward and then abruptly back- l; so that the greater part is more longitudinal than transverse; striae are somewhat subdivided and followed outwardly by ter striae; at the inner end they terminate abruptly, so that from e they have the appearance of 13 truncated shallow teeth. gth 5.2 mm.

his manus resembles that of two common recent species, *P. atus* (Gibbes)[1], and *P. galathinus* (Bosc)[2], both found on the At- ic as well as on the Pacific side of the continent. The upper face of the palm is similar in *P. armatus*, that is, it is ornamented short, irregular striae, which are, however, parallel to the inner gin, while in the fossil form they diverge proximally from the gin. The lower surface of *P. avitus*, on the other hand, resembles e closely that of *P. galathinus*, but in the latter, the striae trend e strongly forward on leaving the inner margin, and that margin f is not formed of such strongly marked teeth.

Superfamily THALASSINIDEA.

Family AXIIDAE.

AXIUS RETICULATUS, new species.

Plate 57, figs. 2 and 3.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail- Cut. From lowest fossiliferous bed. Third bed below lowest stone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*.

olotype.—Cat. No. 324260, U.S.N.M. Left propodus of first iopod, embedded in a nodule and showing the finger and the ter part of the palm, except the proximal end and the distal er corner. An impression of the same is shown in another piece ne nodule. The segment as uncovered is 14.3 mm. long, greatest ht 5 mm., length of finger 7 mm. The palm is greatly swollen at the top rounds over into a broad upper surface about 2.4 mm. idth. The shell is considerably cracked and in life may not have as thick as it appears. The lower margin is sinuous, forming a at about the distal third of the palm; so far as the edge is pre- ed it is formed of small bead granules. The outer and upper ace is ornamented with granules irregular in size and disposi-

[1] *Porcellana armata* Gibbes, Proc. Amer. Assoc. Adv. Sci., vol. 3, 1850, p. 190.
[2] *Porcellana galathina* Bosc, Hist. Nat. Crust., vol. 1, 1802, p. 233, pl. 6, fig. 2.

tion, larger and thicker on the distal part midway between upper and lower margins, elsewhere smaller and to a large extent forming a reticulate pattern; proximally on the upper part of the outer surface the raised reticulate lines are smooth, or non-granulate.

The outer surface of the finger is rather regularly tapering, the lower margin directed slightly upward, the superior margin nearly straight; surface smooth; finger thick, the upper surface obliquely beveled; traces of fine teeth are visible on the prehensile edge.

AXIUS?, species.

Plate 57, fig. 10.

Locality.—Panama Canal Zone. From near Mount Hope, in ditch through swampy ground. About one-quarter mile from present ocean beach, 6 to 8 feet above high tide. Pleistocene series. D. F. MacDonald, collector. April, 1911. Station 5850. Cat. No. 32450, U.S.N.M.

Material.—A single movable spine, 6.7 mm. long, with the tip broken off, resembles the styloid scaphocerite or movable acicle of the outer antenna of some species of *Axius*. The spine is somewhat 3-angled, the most acute edge being dorsal, the two blunt edges being nearer together and ventral. There are a few punctae: 4 large ones in a row on the ventral surface; 2 large, external, far apart, just below the upper margin; 4 small ones, internal, 3 of which form a triangle near the middle, while the other is nearer the distal end.

Family CALLIANASSIDAE.

KEY TO THE SPECIES OF CALLIANASSA HERE DESCRIBED.

The material is insufficient to distinguish between the larger and the smaller chela of the same pair, which also may vary in shape and size in the two sexes.

A¹. Manus and carpus meeting in an oblique line.
  B¹. Lower margin of manus serrated ..... *ovalis*, 137
  B². Lower margin of manus smooth ..... *lacunosa*, 138
A². Manus and carpus meeting in a vertical line.
  B¹. Lower margin of manus directed forward and upward, at least in part.
    C¹. Palmar portion of manus distinctly longer than high.
      D¹. Palm compressed.
        E¹. Palm elongate; margins strongly convergent ..... *elongata*, 139
        E². Palm less elongate; margins moderately convergent ..... *scotti*, 140
      D². Palm swollen ..... *moinensis*, 142
    C². Palmar portion of manus about as long as high, or shorter. Upper margin of manus directed forward and downward toward the ventral margin.
      D¹. Immovable finger very thin, a cross-section near its base being more than twice as long as wide. A strong tooth in the sinus between the fingers or on the base of the immovable finger ..... *spinulosa*, 143
      D². Immovable finger thicker, a cross section near its base being less than twice as long as wide. A tooth in the sinus between the fingers but near the base of the dactylus ..... *tenuis*, 144

Manus and carpus meeting in a vertical line—Continued.
³. Lower margin of manus directed straight forward or nearly so; that is, at right angles to its proximal margin.
C¹. Upper margin of manus subparallel to lower margin. No tooth in sinus between fingers. Carpus much higher than long.
D¹. Lower margin serrulate—*quadrata*, p. 145
D². Lower margin granulate—*toulai*, p. 146
C². Upper margin of manus directed forward and downward toward lower margin.
D¹. A large tooth in sinus between fingers and situated on base of immovable finger—*abbreviata*, p. 147
D². A small tooth in sinus between fingers, and situated near movable finger. Carpus very little, if at all, higher than long—*hilli*, p. 148
D³. No tooth in sinus between fingers. Fingers long and strong. *vaughani*, p. 148
³. Lower margin of manus unknown. A stridulating ridge near the horizontal upper margin—*stridens*, p. 151
Meeting of manus and carpus unknown.
¹. Immovable finger slender. Distal articulating edge of manus crenulate and very oblique—*crassimana*, p. 141
². Only the dactylus known.
C¹. Dactylus of large size. Cross section at base subcylindrical. Prehensile edge thin—*magna*, p. 151
C². Dactylus half as long as preceding, more compressed. Prehensile edge thicker—*crassa*, p. 152

The 2 Callianassas to which specific names are not given are excluded from the above key.

CALLIANASSA OVALIS, new species.

Plate 59, figs. 1–4.

Type-locality.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. From lowest fossiliferous bed, third bed below lowest limestone beds separated by rows of nodules. Lower part of upper member of Culebra formation. Oligocene series. D. F. MacDonald and T. W. Vaughan, collectors. 1911. Station 6020*a*. Holotype and one paratype. Cat. No. 324269, U.S.N.M.

Holotype.—A left chela with wrist and arm attached, and enclosed in a nodule which is split in two. The specimen had been crushed, and the half nodule containing the impression shows also small portions of the cheliped itself. Wrist and manus together oblong-ovoid; line between them oblique; upper and lower margins of manus slightly convex; greatest width about equal to the upper length; from the widest point, the lower margin of the propodus slants upward. Fingers directed straight forward and of subequal length. Immovable finger an isosceles triangle, the base of which is two-fifths as long as either side; end blunt; cutting edge with a shallow triangular tooth at the proximal two-fifths. Movable finger subcylindrical, end broad, cutting edge with a broad, shallow, rounded tooth

near the base. The merus appears to be about twice as long as
and is dilated at the middle.

Measurements.—Length of carpus and propodus, measured f
lowest point of articulation with merus to end of propodal fi
20.5 mm.; proximal width of propodus (approx.), 9.4 mm.; gre
width of same, 10 mm.; distal width of same, 8.7 mm.; sup
length of same, 10.2 mm.; inferior length of same, 13.2 mm.; le
of propodal finger measured on cutting edge, 5.7 mm.; lengt
dactylus, 5.7 mm.

Paratype.—(*a*) Left manus with part of the fixed finger,
bedded in a nodule and exposing the outer surface. Larger
holotype. The lower margin of the manus has blunt serra
resembling the stumps of spines; above the margin is a row of
distant punctae; at the distal end there are two rows of gra
leading toward the upper part of the fixed finger.

Paratype.—(*b*) Carpus of left cheliped embedded in a nodule
imprint of same, showing the distal and upper margins and a
part of the outer surface. The distal margin is oblique and co
and has a little rounded lobe at each end; the upper margin is ar
and has a submarginal groove.

CALLIANASSA LACUNOSA, new species.

Plate 59, figs. 6–11.

Type-locality.—One-quarter mile south of Empire Bridge, C
Zone, Panama; from lower dark clay beneath lower conglome
Lower part of Culebra formation. Oligocene series. D. F.
Donald and T. W. Vaughan, collectors. 1911. Station 6012*a*.
specimens, each a left propodus of the first cheliped. Cat. No.
324278, U.S.N.M.

Holotype.—The palmar portion of a propodus, the fixed f
broken off near its base; the propodus is incomplete near the dac
and also at the proximal end; this end is, however, fairly com
on the inner surface, so that the measurements may be stated
approximate accuracy. Length, at the level of the sinus bet
the fingers, 16 mm.; greatest height, 15.6 mm.; least height, 15.2
thickness, 6.6 mm. The upper margin is a little arched, the
nearly straight; they converge a little distally; they are very
the top of this thin edge along the upper margin is set with o
tubercles, dorsal in position; the lower edge is smooth. The
surface has a row of 6 pits a little above the edge and fairly e
spaced; they have a raised edge and are distally inclined, indic
that they were sockets for hairs or bristles; 3 similar pits far
are close up under the upper margin; of the few scattered p
form a triangle at the distal end, the one near the base of the

ger being the largest; there is also a medium-sized pit a little ow the middle, while 3 small ones are visible near the proximal . A prominent blunt ridge runs from near the top of the fixed ger obliquely backward and upward for a short distance on the m; near this ridge, but chiefly above it, and partly behind it, re is a patch of low tubercles, mostly oblong but very irregular shape and size. On the inner surface there is a row of 8 sockets ttle distance below the thin, upper, marginal rim; these sockets, le of good size, have very narrow, perpendicular openings. Above lower margin there is a row of 12 sockets; this row distally approaches close to the edge, while the sockets themselves become larger farther apart; they are very oblique to the margin and are ost more distal than lateral in their inclination. These 2 rows ockets on the inner surface are more prominent than any others; ow the middle there are 10 or 12 scattered sockets mostly small; r the middle there is a patch of tubercles, somewhat masked by in layer of adhering matrix. On the inner surface there is a t ridge leading back from the finger similarly placed to that on outer surface, but lower and wider. The finger is slender, judging n the section at its base.

aratype.—This propodus shows the outline of the proximal end, the distal end is broken off and not a vestige of the finger remains. size is less than in the holotype: length, at the level of the sinus veen the fingers, 10.3 mm.; greatest height, 11.4 mm.; least ght, 10 mm.; thickness, 5.2 mm. The margins are more convergent than in the holotype and the palm is relatively shorter. The er as well as the lower edge is almost smooth. On the outer sur- the sockets in the upper submarginal row are 4, as there is an itional one visible at the proximal end; the sockets of the lower are fewer and more distant than in the larger specimen, as only n be detected; of the scattered sockets, 3 form a distal triangle, le 10 or 12 small ones are disposed transversely near the proximal ; the protuberances above the oblique ridge leading from the fixed er consist of a few small granules. On the inner surface, a of 8 submarginal sockets above, as in the holotype; near the er margin only 10 sockets can be counted, because the distal ier is broken away; scattered sockets 16 or 18, below the middle; w granules close to the sinus between the digits.

CALLIANASSA ELONGATA, new species.

Plate 60, figs. 4–6.

ype-locality.—Panama Canal Zone. Las Cascadas section, lard Cut. From lowest fossiliferous bed, third bed below lowest stone beds separated by rows of nodules. Lower part of upper

half of Culebra formation. Oligocene series. D. F. MacD and T. W. Vaughan, collectors. 1911. Station 6020*a*.

Holotype.—Cat. No. 324271, U.S.N.M. A left manus, with of immovable finger attached; this shows all of the outer su except the margin bordering the dactylus; nearly the whole o inner surface is concealed by the matrix. The upper margin is straight throughout its length, and is bluntly angled; lower m very sinuous, the manus being very much deeper in its pro than its distal half, edge serrulate or spinulous throughout its le proximal edge vertical, nearly as long as upper margin. O outer surface there is a group of granules at the distal two-se and just below the middle; there is a curved row of granules the sinus, which is continued upon the propodal finger near its edge; 6 granules in all are visible. Finger very slender, inc downward. The dactylus must have been very stout, and the cent edge of the manus very oblique, but it is now incomplete.

Measurements.—Superior length of manus (approx.), 15.7 length to sinus, 20.4 mm.; greatest height, 16.2 mm.; proximal h (approx.), 15.1 mm.; distal height, 12.4 mm.

CALLIANASSA SCOTTI Brown and Pilsbry.

Plate 60, figs. 9–12.

Callianassa scotti Brown and Pilsbry (part), Proc. Acad. Nat. Sci. Phila. vol. 64, 1913, p. 503, pl. 22, figs. 1 and 3 (not fig. 2).

Locality.—Panama Canal Zone. From the 4 feet of dark s fied tuff and clay immediately overlying the lower limestone Las Cascadas section. Upper part of Culebra formation. C cene series. D. F. MacDonald and T. W. Vaughan, collectors. Station 6019*b*. Cat. No. 324279, U.S.N.M.

Material.—A left manus, removed from the matrix, and in plete at the proximal end. Outer surface very convex from up lower margin; upper margin straight, with a blunt marginal lower edge acute and serrulate with fine appressed teeth or s inclined upward toward the base of the finger, then downwa three granules or tubercles in a curved row just outside the ed the sinus between the fingers. The cross section of the finger its base is very small, in relation to the manus. Inner su slightly convex, from upper to lower edge, and with a depressi either side of the base of the fixed finger; numerous granules the distal end, some arranged in a curved band between the fingers.

Measurements.—Greatest height of manus, 25.2 mm.; least h of same, 23.3 mm.; length of same to digital sinus, 24.6 mm.; thic

same, 10.9 mm.; greatest diameter of fixed finger near its base, mm.; least diameter of same, 4.2 mm.

olotype and paratypes.—In the material included by Mr. Brown Dr. Pilsbry under *C. scotti* are specimens of three species; two hese species were figured with the original description; the larger ies illustrated[1] by figures 1 and 3, plate 22, is chosen to bear the ne *scotti*, and the original of figure 1 may be designated as the e-specimen, as it is free from the matrix and shows more of the racteristic granulation than does the original of figure 3, which rnished with a propodal finger, but is half embedded in a matrix. lso shows, although roughly, a row of 5 pits on the upper margin; row, however, slopes downward a little distally on to the inner face. The greatest height of the type is 27 mm., length at level of s between fingers, 28 mm.

till a third specimen, also a left manus, was taken at the same e; the surface is much worn, but the proximal angles are well de- d. The type-locality is in the lignitic layers, about 65 feet below base of the *Pecten* bed at Tower N., Las Cascadas section, Gail- Cut; Prof. W. B. Scott, collector, 1911. Type, Cat. No. 2259, s. Acad. Nat. Sci., Philadelphia.

he hand mentioned by Brown and Pilsbry,[2] as collected by W. M. b in Costa Rica, apparently belongs to *C. scotti*. It shows well upper marginal row of pits, numbering 7, which drops distally o the inner surface. The specimen is labeled "Miocene." Cat. 2255, Mus. Acad. Nat. Sci., Philadelphia.

CALLIANASSA CRASSIMANA, new species.

Plate 61, figs. 15–17.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail- n Cut. From lowest fossiliferous bed, third bed below lowest li- stone beds separated by rows of nodules. Lower part of upper h of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*.

easurements.—Distal height of palm, 22 mm.; thickness of palm, east 7.7 mm.; length of crenulated lobe bordering dactylus, 10.2 m.; upper length of dactylus (tip broken off), 18 mm.; greater diameter at the break near the tip, 1.7 mm.; lesser diameter at same pot, 1.3 mm.; greater diameter at a break about middle of finger, 8 mm.; lesser diameter at same point, 2.8 mm.

olotype.—Cat. No. 324273, U.S.N.M. A portion of the distal end of he left manus with the propodal finger attached; embedded in a ule. This must have been a very large specimen. The oblique

[1] Proc. Acad. Nat. Sic., Phila., vol. 64, 1913, p. 503 [2] Idem, p. 504.

margin of the lobe of the manus which overlapped the dactyl very oblique and is straight and deeply crenulated with abou crenules; the length of the lobe is as great as the distance acros adjoining sinus and the propodal finger. This sinus is very and proximally subtruncate. The immovable finger is very narr relation to the size of the palm; it is slightly compressed, and upward; on the inner surface just within the lower margin the a row of punctae; on the outer face there are 3 larger spots, 2 the lower margin and one near the sinus, which may be socket setae. A tubercle on the outer surface just behind the sinus. inner surface of the manus is deeply channeled out near the between the fingers.

The holotype is in two pieces, as the immovable finger is brok two, the distal portion embedded in that half of the nodule w bears the imprint of the remainder of the holotype.

This species is very near *C. scotti*, but has a larger sinus bet the fingers, a longer propodal finger, and a shallower sinus i lower margin of the manus just behind the finger.

CALLIANASSA MOINENSIS, new species.

Plate 60, figs. 1–3.

Type-locality.—Moin Hill, near Limon, Costa Rica. Prob equivalent to Gatun formation. Miocene series. H. Pittier, coll Propodus of right cheliped, and an impression of half a finger.

Measurements.—Length (approx.) of manus, to sinus bet fingers, 9 mm.; height of same, 7 mm.; thickness of same, 4.7 length of immovable finger (tip broken off), 8.6 mm.

Holotype.—Cat. No. 324287, U.S.N.M. Palm much swollen, section ovate, lower margin viewed from the side very arcuate, margin slightly so. The surface has almost entirely lost the white layer, but the next layer is gray and is crossed transverse many very short rugae, which are strongest on the lowest part outer surface. There is a distinct line below dividing the inner the outer surface and marked by an irregular row of very punctae. On the inner surface considerably below the upper m there is a row of large punctae.

The immovable finger is slender, bent downward and c inward. It has 7 more or less defined ridges, the bluntest of is the most inferior; either side of the ridge representing the hensile edge there is a granular ridge, the outer of which i elevated; in addition, there are 2 ridges on the outer surface an on the inner; near each ridge there is a row of fine punctae. hensile edge armed with small irregular teeth. There is an unus deep furrow above the principal ridge on the inner surface.

Paratype (*a*).—Cat. No. 324287, U.S.N.M. On a small piece of mbling rock there is an impression of the distal half of a finger, not the finger of the holotype. The impression has a similar vature and 3 rows of punctae are present.

Paratype (*b*).—Cat. No. 324288, U.S.N.M. Moin Hill, Costa Rica; d fossiliferous zone below the uppermost; just below level of rails railway cut. Probably equivalent to Gatun formation. Oligocene iod. D. F. MacDonald, 1911. Station 5884*d*. A right propodus hout finger, similar in size to the holotype and corresponding in characters.

CALLIANASSA SPINULOSA, new species.

Plate 61, figs. 6–9.

Callianassa scotti PILSBRY (part), Proc. Acad. Nat. Sci. Phila., vol. 64, 1913, p. 503 (not pl. 22, figs. 1–3).

Type-locality.—Panama Canal Zone. Las Cascadas section, Gail- l Cut. From lowest fossiliferous bed, third bed below lowest estone beds separated by rows of nodules. Lower part of upper f of Culebra formation. Oligocene series. D. F. MacDonald and W. Vaughan, collectors. 1911. Station 6020*a*.

Holotype.—Cat. No. 324272, U.S.N.M. Left propodus which was ased in a nodule; the manus has been removed except the proximal t of the outer surface; of the propodal finger only the impression ains. Length of manus less than greatest height; the upper and er margins converge distally, the upper margin convex, the lower uous. Outer surface very convex in a vertical direction, having w scattered granules, also a short vertical line of 3 granules near upper distal corner, a row of 6 distant granules just above the er margin, and a sharp granule near the sinus. The lower margin ery thin and serrated; between the serrations are the truncated es of movable spines; 9 such spines remain. Upper edge bluntly rgined. Inner surface convex except near the inferior and distal rgins; a row of 3 granules on the middle line, 2 above the base of propodus, 2 parallel to the lower margin, and many small granules t above that margin. An obliquely longitudinal line of pits below upper margin.

The propodal finger is very much smaller than the dactylus and n; a cross section near its base is somewhat diamond-shaped, the pression of the thumb (viewed sideways) is subtriangular, end ved upward; prehensile edge concave; at its base in the sinus be- en the fingers there is a short but strong curved tooth; on both er and inner surfaces of the thumb, leading down from the palm, re is an oblique ridge.

Measurements.—Length of propodus to end of finger (approx.), 4 mm.; length of manus, measured on the inner side, to sinus, 14.7

mm.; greatest height (proximally), 15.3 mm.; least height (distal)
13.3 mm.

Paratypes.—(*a*) One left propodus with about half of the fi
finger attached was taken in the lignitic layers, about 65 feet be
the base of the *Pecten* bed at Tower N., Las Cascadas section, G
lard Cut; central part of Culebra formation, Oligocene series; P
W. B. Scott, collector; 1911 (Mus. Acad. Nat. Sci. Philadelph
The specimen is half embedded in a nodule which conceals the in
surface and the upper part of the outer surface. It is nearly as la
as the type. It shows the large tooth at the proximal end of the
hensile edge of the fixed finger, the tubercle on the outer surface
the sinus between the fingers, and roughly, the ornamentation on
lower edge of the palm.

(*b*) From the same source, a similar left propodus half embed
in a nodule but so as to expose the inner surface and the upper ed
it shows the characteristic row of pits on the inner surface just be
the upper edge, the row sloping downward distally.

(*c*) Also a third specimen, free from the matrix but with the ed
broken; it shows the palmar ridge leading to the fixed finger and
basal tooth on the edge of the latter.

CALLIANASSA TENUIS, new species.

Plate 60, figs. 13 and 14.

Type-locality.—Panama Canal Zone. Las Cascadas section, G
lard Cut. From fifth or topmost limestone. Emperador limest
Oligocene series. D. F. MacDonald and T. W. Vaughan, collect
1911. Station 6019*g*.

Holotype.—Cat. No. 324282, U.S.N.M. Left manus with prop
finger broken off, segment shorter than its greatest height, in gen
subrectangular, with upper and lower margins converging dista
outer surface very convex from top to bottom; upper and lo
edges marginate, the lower one very thin; inner surface convex
cept near the bottom where it is flat, at the proximal end where t
is a furrow parallel with the articulation, and near the distal s
where there is a depression. The propodal finger is very
smaller than the dactylus, and its cross section is suboval
pointed ends; the sinus is about as wide as the thumb; it bears,
up to the insertion of the dactylus and on the edge of the outer
face, pointing forward, a short, broadly triangular spine. Surf
much worn, so that it is difficult to tell whether unevennesses
natural or not.

Measurements.—Length of manus, measured to sinus, 11.4 m
greatest height, 13 mm.; distal height, 10.3 mm.; thickness, 5.3 m

CALLIANASSA QUADRATA, new species.

Plate 62, figs. 4–14.

Callianassa scotti BROWN and PILSBRY (part), Proc. Acad. Nat. Sci. Phila., vol. 64, 1913, p. 503, pl. 22, fig. 2 (not figs. 1 and 3).

epresented by 2 specimens of the left manus from which the podal finger has been broken off. The smaller one is used as type, as it is the better preserved.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail- Cut. From lowest fossiliferous bed, third bed below lowest stone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*. Holotype paratype. Cat. No. 324275, U.S.N.M.

asurements (in mm.).—

	Holotype.	Paratype.
Height of manus near middle	13.3	15.3
Length of manus measured to sinus	12.8	15.7
Thickness of manus	6.2	7.5

olotype.—Hand squarish, with the corners rounded off. The er and lower margins are subparallel, the upper slightly arched, lower with a shallow distal sinus. Distal margin, at the articula- with the dactylus, nearly vertical. Outer surface slightly con- in a longitudinal direction, strongly convex vertically, furrowed ne distal end across the middle third; inner surface moderately ex except at the distal and lower portions, where it is concave; e is a groove just above the lower margin which widens as it ap- aches the finger. Lower margin serrulate; upper margin bluntly ed except in the distal third, where it is rounded; just within margin there is a row of sockets of which 3 can be made out. the outer surface near the sinus between the fingers there is a rcle and near the carpus 3 granules far apart in a vertical row; he inner surface there is a row of granules, running almost longi- nally near the middle and thence downwards toward the sulcus een the fingers; 2 tubercles near the articulation with the dac- s. Propodal finger narrow, much compressed, subtriangular at base in cross section, with the small end of the triangle down. e of dactylus very large.

ratype (*a*).—Larger than the type; upper margin straighter; tubercle on the outer surface near the sinus is of good size; on nner surface near the middle there are numerous granules instead ne single row in the holotype; 2 tubercles near the dactylus.

oubtful specimen.—A single specimen of a left carpus, from the e locality as the types may belong to the same species. The r surface is mostly concealed by the matrix. Outer surface

very convex from the upper to the lower margin; convexity ak
that of the manus of this species, which is the reason for pla
the carpus here rather than with *Callianassa elongata* or any
species occurring at the same locality. Carpus about 1⅔ time
high as its greatest width, which is in the upper part; the a
formed by the superior and the distal margins is a little less th
right angle; superior margin straight; distal angle projecting a
the articulation with the manus. The inferior distal angle pro
even more below the articulation; the angle is obtuse; from i
margin rounds downward and then upward in a single curve
lowermost part is finely serrate.

Measurements.—Height of carpus, between distal angles,
mm.; greatest height, 18.8 mm.; greatest width, 12.8 mm.; widt
upper margin, 12 mm.; greatest width below the articulation wit
merus, 11.8 mm.

Four specimens before me from the collection of the Acaden
Natural Sciences of Philadelphia belong to this species; they ar
right and three left chelae and form part of the material referre
Brown and Pilsbry to their *C. scotti.* (Paratype *b*) One left
is that figured on plate 22, fig. 2.[1] All are larger than the type
terial described above, but so far as their characters are pres
they agree in essentials with the type. (Paratype *c*) The right
(the largest specimen) its about 23 mm. long by 21.2 mm. wide
possesses a longer piece of the propodal finger than the other s
mens; the exposed cross section of the finger is oval. (Paraty
The shortest of the left chelae has a large part of the outer layer
served on the infero-distal and inferior surface, where it is co
with granules, arranged without regularity except for a row o
outer surface parallel and close to the lower edge. This row i
visible in my figure 14, plate 62. The longest of the left c
(Paratype *e*) is about 24 mm. by 19 mm., that is, considerably
rower than (*c*).

CALLIANASSA TOULAI, new species.

"Krabbenscheren" TOULA, Jahrb. der k. k. Geolog. Reichsanstalt, v
1911, p. 512 [26], pl. 30 [1], fig. 14.

Founded on two chelae, one with palm 20.6 mm. long, 16.5
wide, the other (without movable finger) with palm 9.4 mm.
5.5 mm. wide.

Outer surface of palm arched, inner surface almost flat and w
flat depression close to the lower margin and extending fro
fixed finger. The upper and lower margins are sharp, the fo
bears 3 spinelike projections directed forward, the lowest spine

[1] Proc. Acad. Nat. Sci. Phila., vol. 64, 1913, p. 503

sharp margin; lower margin very finely and sharply granulate he finger tip. Outer surface smooth and glossy, thickly covered r the lower margin with fine granules. Inner surface covered n very small, oblong punctae. A stout tooth on the prehensile gin of the immovable finger visible from the outside; another h on the movable finger, visible from the inside.

ype-locality.—Gatun. Miocene series.

CALLIANASSA ABBREVIATA, new species.

Plate 63, figs. 1–6.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail- l Cut. From lowest fossiliferous bed; third bed below lowest estone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*. 4 specimens.

Types.—Cat. No. 324274, U.S.N.M.

Measurements.—Length of manus to sinus, 10.3 mm.; greatest ght, 10 mm.; distal height, 8.4 mm.

Holotype.—Specimen of right manus partially embedded, showing ter surface and half of outer surface; an imprint of the inner sur- e of the holotype is seen on a separate piece of rock. Length and ght subequal; infero-proximal angle a right angle, upper margin vex. Outer surface slightly convex from end to end, more so from t to bottom. Inner surface equally convex in both directions, with rrow close to the proximal end; an oblique furrow near the lower e, directed slightly upward distally, and a depression leading to sinus between the fingers and to the adjacent part of the immov- e finger; on the oblique raised line below this depression, there is ow of 4 granules. Upper and lower edges margined; the lower re shows, in the impression, about 18 dots, but whether these are nctae or spinules on the outer surface can not be told. There is a e of 6 punctae just within the upper margin. A few scattered nctae on inner surface. An oblique cross section of the thumb is ull and somewhat diamond-shaped; above this section there is a nt tooth; sinus between the 2 fingers V-shaped. The impression ws a little more of the length of the thumb than remains in the e, but represents neither the full length nor width.

Paratype (*a*).—Left manus, larger than the holotype, and free m the matrix; immovable finger broken off; edges worn; inter- ital tooth present, and near by on the outer surface, a granule.

Paratype (*b*).—A fragment, comprising the distal lower end of propodus with broken finger attached; interdigital tooth present.

CALLIANASSA HILLI, new species.

Plate 58, figs. 18–20.

Type-locality.—Gatun beds, Panama Canal Zone. Gatun for tion. Miocene series. Robert T. Hill, collector; Station 18.

Types.—Cat. No. 135218, U.S.N.M.

Measurements.—Greatest height of carpus of right cheliped, mm.; superior length of same, 10.3 mm.

Material.—3 pieces of rock from the same place contain fragm of *Callianassa* which belonged to at least 2 specimens and prob represent a single species. The largest piece contains 2 fragme each consisting of a right merus and carpus (the better preserve these may be considered the holotype); the imprint of a right v and hand; the distal half of a right propodus and a portion of dactylus. The second piece of rock has been broken from the and contains the continuation of the right propodus, with ca and merus attached (paratype *a*), also the first 4 segments of third right leg. The third piece of rock contains the sixth joint of tail (paratype *b*). The following description is compiled fron the specimens:

The merus of the right cheliped has the outer margin promine carinate with a smooth rounded carina; upper margin granul In both instances the merus is so flexed beneath the carpus that lower margin is not visible. The carpus is about equally long high; its upper margin is slightly convex to a point near the artic tion with the merus: distal margin slightly concave, but nearly tical; margin from the infero-distal angle to the merus strongly a ate. Manus about as long as high, moderately convex, outer sur more so than inner; lower margin nearly straight; just above i inner surface a row of many fine punctae from which setae may sprung; this row is continued on the propodal finger; the latt only partly uncovered; it is flat on the inner side, at least half as as the manus and its lower margin is a straight line continuous that of the manus.

The right leg of the third pair is very much like the correspon member in *C. stimpsoni* Smith, the *Callianassa* of the Atlantic of the United States.

The sixth segment of abdomen or tail is subrhomboidal, with a striction behind the middle; the segment is much wider in f than behind; the depressed portion at the anterior middle was hi in life under the fifth segment.

CALLIANASSA VAUGHANI, new species.

Plate 63, figs. 10–13.

Type-locality.—Panama Canal Zone. From 85-foot cut on r side of big swamp on relocated line, Panama Railroad; 1½ to 2 r

ond Camp Cotton toward Monte Lirio. Gatun formation. cene series. D. F. MacDonald and T. W. Vaughan, collectors. l. Station 6030. Holotype and 2 paratypes. Cat. No. 324285, .N.M.

olotype.—Portion of the right claw, comprising the distal end of manus and both fingers; outer surface only. Height of manus at al end equal to length of dactylus measured on the chord from the o the middle of its articulating edge; surface convex from upper ower edge. Fixed finger wide in its proximal half, then abruptly owed; distal half directed slightly upward; length twice as great asal width. The ends of the fingers are somewhat crushed; the able finger curves strongly downward and appears to overreach tip of the immovable finger, being at right angles to it; its lower has two teeth, one near the articulation squarish, broader than , the other smaller, separated by a rounded sinus. At the sinus l to this tooth is the widest interdigital gape; a little further on fingers would meet for a ways, if they were closed, while the tips ld cross each other. The greatest width of the dactylus is a little e than a third of its greatest length, measured in a straight line. he oblique edge of the propodus which projects over the dactylus enulate. On the manus near the gape of the fingers there are 3 rcles in a curve parallel with the edge. Behind the crenulation e are 2 scale-like sockets from which setae probably arose, and nd these a vertical thumb-nail impression. Near the superol angle of the manus there is another socket. On the proximal of the dactylus there are 9 sockets of larger size than those on manus and irregularly disposed; 2 are on the larger prehensile n and one on the smaller.

ratype (a).—Left manus, both sides visible. A smaller speci- than the holotype. Upper and lower margins distally converg- Length a little more than greatest width. Outer surface con- n both directions, but more so from top to bottom. Surface for most part smooth and shining. The ornamentation is like that e type, that is, a crenulated edge on the lobe which overlaps the ylus, a row of tubercles just behind the gape—the lower of the bercles is broken off—above this 2 sockets, and then a very short nb-nail impression, followed by a socket near the upper angle. upper margin is subacute in its proximal half, becoming gradu- blunt toward the distal end; on either side is a row of sockets; visible on the outer surface and 5 on the inner; lower margin , also with a row of sockets on either side; 5 are visible on the side and about 10 on the inner side in the distal half; the imal half is broken. There are a few punctae scattered about outer surface; while on the inner surface near the depression

leading to the gape there is a double row of granules, 8 of w
can be made out. The edge overlapping the dactylus is crenulat
the inner surface.

Paratype (*b*).—Portion of left propodus showing part of fi
and a small part of the manus. Surface shining. Three tube
near gape, and continuing the same curve along the upper part o
outer surface of the finger, there is a granule followed by 2 soc

Measurements.—(Approximate only.) *Holotype:* Distal he
of manus, 19.3 mm.; length of dactylus from tip to proximal en
upper margin, 23.5 mm.; height of dactylus, measured straigh
from the edge of the basal tooth, 8.6 mm.; length of immov
finger measured along the prehensile edge, 15 mm.; height of
at base, 7 mm. *Paratype* (*a*): Length of manus across middle,
mm.; proximal height, 16.7 mm.; distal height, 15 mm.; gre
thickness, 6.6 mm. *Paratype* (*b*): Height of immovable finge
base, 5.8 mm.

Additional localities.—Panama Canal Zone. Las Cascadas
tion. From lower part of lime-cemented soft gray to olive-col
limestone with central parting of dark clay. The first hard,
sandstone bed above the lower limestone just above Station 6
Upper part of Culebra formation. Oligocene series. D. F.
Donald and T. W. Vaughan, collectors. 1911. Station 6019*c*.
left propodus with most of the fixed finger attached. The spec
is so bruised and crushed that its identity can not be determined
certainty. Cat. No. 324283, U.S.N.M.

Also, from the same place, a right dactylus from a chelipe
much smaller size. Its identity is uncertain. It lacks the large
on the cutting edge, but it may belong to the feebler of the
chelipeds, or to a female. There is evidently a shallow sinus a
base, followed by a low broad tooth. Six sockets for setae ca
made out. The thick outer crust has nearly all broken away.
No. 324283, U.S.N.M.

Panama Canal Zone. From lowest horizon in big cut from $\frac{1}{4}$ o
mile beyond Camp Cotton toward Monte Lirio. Lower pa
Gatun formation. Miocene series. D. F. MacDonald and T. W.
Vaughan, collectors. 1911. Station 6029*a*. Left manus, abou
mm. long, measured at the level of the articulating condyle o
dactylus; edges mostly broken and obscured. Identification
(1) on the general contour of the surface, (2) the color, a light
(3) the margin adjacent to the articulating condyle of the dac
and (4) 2 sockets just below the upper margin on the inner su
Cat. No. 324284, U.S.N.M.

CALLIANASSA STRIDENS, new species.

Plate 61, figs. 12–14.

ype-locality.—Panama Canal Zone. From third hard sandstone from bottom. Las Cascadas section. Upper part of Culebra for- ion. Oligocene series. D. F. MacDonald and T. W. Vaughan, ectors. 1911. Station 6019*e*. Cat. No. 324281, U.S.N.M.

olotype.—Manus of a left cheliped. Only the upper two-thirds isible, the lower third is embedded in rock. Upper margin zontal, distal and proximal margins vertical, supero-posterior ier rounded. Upper edge thin, a little sinuous, viewed from the On the inner surface a little below the upper edge there is a of 8 short vertical ridges, which occupies the whole length of segment. This may have been a stridulating mechanism.

easurements.—Superior length of manus, 11 mm.; thickness, nm.

CALLIANASSA MAGNA, new species.

Plate 62, figs. 1–3.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail- Cut. From lowest fossiliferous bed. Third bed below lowest stone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*. Cat. No. 70, U.S.N.M.

easurements.—Greatest length of movable finger (tip broken 33 mm.; greatest height, 13.2 mm.; thickness, 0.8 mm.; length asal sinus, 6 mm.

olotype.—The only specimen is a movable finger or dactylus of right cheliped. It is very much worn and a considerable portion he tip is lacking. The lower border is thin, but the remainder hick and in cross section subcircular, and tapers gradually to- l the distal end. At the proximal end below there is a broad s; the thin prehensile edge is slightly concave, viewed from out- , and feebly denticulate, especially when viewed from inside; e is a somewhat larger and better preserved tooth just within the gin at the widest part of the finger. Upper margin in outer view ght in its proximal half, gently curved distally. In dorsal the finger is much curved and in the middle of its upper surface e is a longitudinal row of four large punctæ.

its general shape, including the basal sinus, this dactylus re- bles that of *C. pellucida* Rathbun, from the Leeward Islands, scription of which is about to be published by the Carnegie In- tion, but the prehensile edge is thinner and more laminate and inner outline more concave in dorsal view instead of almost ght as in that species.

CALLIANASSA CRASSA, new species.

Plate 61, figs. 1–3.

Type-locality.—Gatun section A, bed A (bottom of sect
Lower part of Gatun formation. Miocene series. D. F.
Donald, collector. Station 6003. Two dactyli of the left chel

Types.—Cat. No. 324276, U.S.N.M.

Measurements.—Length of dactylus, 16.3 mm.; height, 6.2 mm

Holotype.—Outer and upper surfaces exposed, outline of ti
scure. Viewed from the outside the upper outline is arcuate an
tip bent down below the prehensile edge, which is nearly horizo
Viewed from above, the outer line is much curved and the inne
nearly straight. On the prehensile edge there is a shallow
sinus, followed by a very low, broad tooth; rest of margin fa
sinuous. The surface shows a number of granules, some large, o
small; the large ones are about 7 on the outer surface and 5 o
upper surface; of the former, 2 are submarginal, one of them
above the lobe, the other half way to the tip; the other 5 ext
granules are disposed on the distal half; the 5 superior granule
arranged in 2 rows, one row of 3 toward the inner surface, an
other row of 2 granules toward the outer surface; the proxim
these is double. On the middle of the outer surface there is a
of about 50 small granules. The chalky-white outer layer of the
has crumbled away except near the edges, so that one can no
whether the granules were apparent on that surface. Color o
face now exposed dull light bluish.

Paratype.—About two-thirds as large as the holotype, and
both ends of the finger missing. Granules as follows: 3 large
the lower margin, 2 as in the holotype, the other above the
sinus; on the inner surface are 3 similarly spaced but placed
distad. On the upper surface there is a row of 4 toward the
surface, and below the second one from the proximal end are
together. The small granules are more separated than on the
type and are distributed chiefly on the upper half of the
surface.

CALLIANASSA, species.

Plate 59, fig. 5.

Locality.—Panama Canal Zone. Top part of limy sandsto
low upper conglomerate, near foot of stairs, Gaillard Cut.
part of Culebra formation. Oligocene series. D. F. MacD
and T. W. Vaughan, collectors. 1911. Station 6012*c*. Ca
324277, U.S.N.M.

Material.—Manus of left cheliped of a small specimen. Out
face visible. Very convex from top to bottom, a deep groove
the edge articulating with the carpus; upper and lower margi
defined.

CALLIANASSA ?, species.

Plate 64, fig. 10.

cality.—Panama Canal Zone. Las Cascadas section. From part of lime-cemented soft gray to olive-colored limestone central parting of dark clay). The first hard, limy sandstone above the lower limestone just above station 6019*b*. Upper part ulebra formation. Oligocene series. D. F. MacDonald and . Vaughan, collectors. 1911. Station 6019*c*. Cat. No. 324280, N.M.

terial.—One small specimen resembling in shape the merus of the smaller of the chelipeds of the first pair. If the above be correct, this is from the right cheliped. The two oblique ves near the distal end may have been artificially produced.

Family PAGURIDAE.

PETROCHIRUS BOUVIERI, new species.

Petrochirus cf. granulatus Olivier sp." Toula, Jahrb. der k. k. Geolog. Reichsanstalt, Wien, vol. 61, 1911, p. 511 [25], pl. 30 [1], fig. 13.

tun; Miocene (Toula). Not represented in the collection at .

ere are two recent species of *Petrochirus* on opposite sides of continent, namely, *P. bahamensis* (Herbst)[1]=*P. granulatus* vier), which extends from Florida to Brazil, and *P. californi-* Bouvier[2] taken at La Paz, Mexico, and in Ecuador. One of principal differences between them lies in the ornamentation of helae. The right chela of *P. bahamensis* is covered chiefly with haped clusters of granules, all of which trend forward and nt a smooth, oval side-face when viewed dorsally; the clusters in size, and some are composed of only 2 granules, while others epresented by only one granule; all are fringed anteriorly with which fills the interspaces. The right chela of *P. californiensis* similarly clusters and single granules, but the clusters are not haped but round, or nearly round, and are composed of a large th central granule surrounded by small granules tipped with a , horny point; the granules are much more elevated and have a dorsal inclination than in *bahamensis;* the single granules are more numerous than in that species.

e right chela of the fossil specimen figured by Toula resembles of *P. californiensis.*

e left chela of *P. bahamensis* is covered with fan-shaped clusters anules like those on its right chela, but the clusters are more

[1] *Cancer bahamensis* Herbst, Naturg. d. Krabben u. Krebse, vol. 2, 1796, p. 30.
[2] Bull. Mus. Hist. Nat., Paris, 1895, p. 6.

crowded, and single granules are fewer. The left chela of *P. forniensis* is covered with clusters like those on its right chela more crowded, and the granules of which they are composed ar a smaller average size.

The left chela of the fossil agrees more nearly with that o *bahamensis*.

We therefore have a Tertiary species combining the character two Recent species, at least as far as the chelae are concerned, pos ing the right chela of one and the left chela of the other.

Tribe BRACHYURA.

Subtribe DROMIACEA.

Family DROMIIDAE.

Genus GONIOCHELE Bell.

GONIOCHELE? ARMATA, new species.

Plate 57, figs. 11 and 12.

Type-locality.—Panama Canal Zone. Las Cascadas section, G lard Cut. From lowest fossiliferous bed. Third bed below lo limestone beds separated by rows of nodules. Lower part of u half of Culebra formation. Oligocene series. D. F. MacDo and T. W. Vaughan, collectors. 1911. Station 6020*a*. Mov finger of the left cheliped. Cat. No. 324259, U.S.N.M.

Measurements.—Length of movable finger (tip broken off), 19 m width at about the middle, 6 mm.; greatest thickness, 4.5 mm.

Holotype.—The shape is elongate-triangular viewed from out the prehensile edge being nearly straight and the upper edge sli arched; outer surface convex in both directions. The prehe edge has a sinus at its base, defined distally by a broad tooth w is at present truncate, but may have been prolonged in two s teeth; beyond are four teeth separated by rounded sinuses and i their tips missing; the first two are spiniform, the last two l and thin. The upper margin bears 5 low, spaced teeth, while w within and alternating there is a line of 3 teeth. On the outer face are 2 rows of tubercles not far from the margins, 4 in the l and 3 in the upper row; the proximal tubercle in the upper is bifid. On the inner surface are 5 tubercles besides those mentioned, 2 in a longitudinal row in the middle, 2 on the distal a little above the prehensile edge, and 1 small one toward th and behind the middle.

have placed this specimen in *Goniochele*[1] on account of the ylus being armed on both edges, as in *G. angulata* Bell,[2] the of the genus, and because the general shape of the segment is lar. In Bell's species the dorsal surface is smooth.

Subtribe OXYSTOMATA.

Family CALAPPIDAE.

HEPATUS CHILIENSIS Milne Edwards.

Plate 66, fig. 4.

Hepatus chiliensis MILNE EDWARDS, Hist. Nat. Crust., vol. 2, 1837, p. 117.

cality.—Panama Canal Zone. From near Mount Hope in ditch igh swampy ground. About one-quarter mile from present sea l, 6 to 8 feet above high tide. Pleistocene series. D. F. Mac-ld, collector. April, 1911. Station 5850. Cat. No. 324235, N.M.

terial.—Dactylus of right chela, 5.3 mm. long. This little men shows all the essential characters of recent individuals of species: 8 shallow rounded teeth on the lower margin; a row of ercles on the proximal part of the upper margin and a row of ercles just below and on the outer surface; still further down, re tubercles; a stridulating ridge on the inner surface just the upper edge is formed of upwards of 45 fine parallel striae ccupies the greater part of the length of the finger.

tribution of Recent material.—Ranges at the present time from dor to Chile.

HEPATUS, species.

Plate 66, fig. 12.

cality.—Panama Canal Zone. From lower part of lime-cemented gray to olive-colored sandstone (with central parting of dark The first hard limy sandstone bed above the lower lime-just above fossil lot No. 6019*b*. Upper part of Culebra forma-Oligocene series. D. F. MacDonald and T. W. Vaughan, ors, 1911. Station 6019*c*. Cat. No. 324239, U.S.N.M.

terial.—One dactylus of left chela, much worn and incom-at both extremities; the proximal half of the upper margin is vanting. The curves in side view are much like those of *iliensis* Milne Edwards.[3] Both inner and outer surfaces are

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onograph of the Fossil Malacostracous Crustacea of Great Britain, pt. 1, 1857,

, pl. 4, fig. 6.

Nat. Crust., vol. 2, 1837, p. 117.

convex from top to bottom. The prehensile edge has traces small teeth, one near the base and one at about the distal t There are also various depressed granules or pits, namely, a ro 5 small ones on the upper margin; opposite the distal one of t there is a larger one on the inner surface; and 3 or 4 on the surface. These are all sunken so that they do not project abov present surface, which is not the true outer surface.

This finger is not quite so flat inside as *H. chiliensis*.

Measurements.—Length of dactylus, 13.6 mm.; height at mi 3.6 mm.; thickness at middle, 2.7 mm.

CALAPPA COSTARICANA, new species.

Plate 57, fig. 24.

Type-locality.—Costa Rica: City of Port Limon. Port L formation. Pliocene series. Dr. L. A. Wailes. 4269.

Holotype.—Cat. No. 324240, U.S.N.M. A triangular frag measuring about 9 mm. on each margin, representing the pro finger and the infero-distal portion of the palm of a left che the weaker form—that is, without a strong submarginal tooth o characteristic of the stronger chela in *Calappa*. Lower margin sinuous, the tip of the finger directed upward, proximal ha margin armed with 6 strong tubercles directed distally. Just a on the outer side, and beginning nearer the finger-tip there is of 11 smaller tubercles, normal to the surface. The prehensile is nearly straight, inclined at an angle of about 75° with the margin of the palm, and is furnished with 6 large, unequal tub which end at the small sinus which ordinarily exists just belo raised margin surrounding the articulation with the dactylu the upper side of this sinus are 2 small tubercles, and abov point, the specimen comes to an end. The outer surface is c with upward of 40 flattened scale-like tubercles pointing up they are separated from the submarginal row by a smooth d sion. The propodus is thick and the inner surface is bevele bevel for the most part smooth; remainder of inner surface st with very unequal pearly granules and tubercles; interspace cr with fine punctae; 2 sinuous ridges run toward the finger-tip.

This species resembles *C. gallus* (Herbst)[1], which is found at the present time from Florida Keys to Bahia, Brazil. The species differs in the very prominent tubercles of the lower m of the palm and the longer tubercles of the submarginal ro above, on the outer surface.

[1] *Cancer gallus* Herbst, Natur. Krabben u. Krebse, vol. 3, pt. 3, 1803, pp. 18 pl. 58, fig. 1.

CALAPPA FLAMMEA (Herbst).

Plate 61, figs. 4 and 5.

Cancer flammeus Herbst, Naturg. d. Krabben u. Krebse, vol. 2, 1794, p. 161, pl. 40, fig. 2; vol. 3, pt. 3, 1803, p. 19.

ocality.—Near Mount Hope, Panama Canal Zone, in ditch ough swampy ground about one-fourth mile from present sea h, 6 to 8 feet above high tide; Pleistocene series; D. F. Mac-ald, collector. April, 1911. Station 5850. Cat. No. 324237, .N.M.

epresented only by one dactylus or movable finger belonging to stronger chela. The milling of the stridulating ridge on the r surface just below the upper edge is more strongly marked than ost of the recent specimens examined.

easurements.—Extreme length, 15 mm.; width just distal to the er marginal tooth, 4.7 mm.

istribution of Recent material.—From North Carolina to Colom-and Venezuela.

CALAPPA ZURCHERI Bouvier.

Calappa zurcheri Bouvier, Bull. Mus. Hist. Nat. Paris, vol. 5, 1899, p. 190, text-fig.

anama. Lower Miocene.

ot represented in the Museum collection.

CALAPPELLA, new genus.

arapace very little broader than long, without clypeiform ex-sions, but with a spine at the junction of the antero-lateral and ero-lateral borders, and a spine at each end of the posterior der.

ront small, projecting forward beyond the orbits.

rbits small, directed forward.

the narrow front and small orbits, this genus resembles *Calappa*, in its narrow carapace armed with 4 slender spines, it differs n that genus as well as from all other Calappinae.

ype of the genus.—*Calappella quadrispina*, new species.

CALAPPELLA QUADRISPINA, new species.

Plate 58, figs. 1 and 2.

ype-locality.—Panama Canal Zone. Las Cascadas section, Gail-Cut. From lowest fossiliferous bed; third bed below lowest stone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald

and T. W. Vaughan, collectors. 1911. Station 6020*a*. Cat. 324238, U.S.N.M.

Measurements (approx.).—Length of carapace (spines exclu 14 mm.; width (spines excluded), 14.4 mm.

Holotype.—Species represented by one specimen showing pa the carapace and no appendages, enclosed in a nodule which has broken in two. Nodule not much larger around than the carapac

Carapace nearly as long as wide, spines excluded; width bet outer angles of orbits a little greater than posterior margin. C of the antero-lateral margin nearly twice as long as that of postero-lateral margin. Antero-lateral margin divided into 2 p the anterior two-fifths being slightly convex, the posterior th fifths very convex with a tubercle at its middle. Postero-lateral gin somewhat sinuous, but in general concave; posterior ma slightly convex, about twice as long as the slender spine at either which is directed backward and slightly outward. Lateral spine slender, but longer, half as long as the postero-lateral margin pointing obliquely backward.

The central and anterior part of the surface of the carapa lacking. There are, however, two oblique, parallel, branchial rows; between them a row of 3 tubercles and some scattered gran the outer part of the branchial region is higher and rough irregular tubercles which are more or less confluent. Cardiac r high, with a median tubercle on its posterior slope; in almos same plane transversely, but on a lower level, there is another tub on each side just above the postero-lateral margin.

There is a very small hollow in the nodule where the point o front rested, and on the other half of the nodule may be see lower surface of the front where it joined the interantennular se

The orbits are small, their upper and lower margins form two teeth, the innermost advanced, separated by a blunt V-sh sinus.

On the lower surface, the inner tooth of the orbit is conside elevated (that is, ventrally). A sharp ridge runs obliquely ward from or near the epistome, and is armed with a tooth posterior third.

MURSIA MACDONALDI, new species.

Plate 58, fig. 21.

Type-locality.—Panama Canal Zone. Las Cascadas section. or topmost limestone. Emperador limestone. Oligocene series F. MacDonald and T. W. Vaughan, collectors. 1911. One spec part of left cheliped. Station 6019*g*. Cat. No. 324229, U.S

easurements.—Length of palm between articulations, 19 mm.; ght (approx.), 10.2 mm.

epresented by the left palm only, which has the customary Calap- l form, and a portion of the immovable finger; the edges are not shown; two teeth may be seen near the distal end of the upper gin. The only details of the outer surface that can be made out a few large tubercles, more or less compressed as in Recent species *Mursia;* these tubercles number about 15; there is a row of 4 tle above, and subparallel to, the lower margin; from these 4 rcles irregular rows extend obliquely upward, trending toward fingers; including those of the horizontal row, those of the distal que row are 4, of the second row 5, of the third row 3, of the imal row 3; these rows are not strictly parallel nor their tuber- regularly spaced. The lower proximal tubercle is the largest and compressed.

here is an indication of the distal spine of the arm-joint, which be seen in the figure.

esembles *Mursia armata* de Haan,[1] but in that species the prin- l tubercles of the hand are 9, arranged in 3 parallel and fairly lar rows.

MURSIA OBSCURA, new species.

Plate 61, fig. 18.

ype-locality.—Near Panama Canal Station "1910," north of o Miguel locks, Panama Canal Zone. From dark clay, lower of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6010. Cat. No. 25, U.S.N.M.

easurements of fragmentary specimen, 8.2 mm. long, 9 mm. wide.

olotype.—The central part of the carapace, devoid of its margin, ot perhaps the middle of the posterior margin. This fragment bedded wrong side up in a piece of rock; only the thin outer of the specimen remains and its under surface alone is visible. is been referred to this genus because the cavities or pits, which esent tubercles on the dorsal surface of the shell, are arranged as in *Mursia.* There are 5 longitudinal rows of these pits: The an row consists of 3 large pits, one cardiac, one genital, one gas- preceded by 2 small pits side by side; the two lateral rows each side) are very little oblique to the median line, but sub- llel to each other; the inner of these rows consists of 4 pits, the ltimate one being in a transverse line with the last pit of the an row; the last pit of the inner lateral row is round and deep

[1] Fauna Japonica, 1839, p. 73, pl. 19, fig. 2.

and indicates a large excrescence, perhaps a spine, on the dorsal face; 3 pits only are visible in the outer row, the middle pit transverse line with the anterior pit of the other rows, whil anterior pit of the outer row is not quite in line with the two be it. Either side of the pair of small submedian gastric pits th a large cavity. The furrows separating the branchial fron gastric and cardiac regions are indicated by sinuous ridges.

Judging from the proximity of the rows of pits, this carap narrower in proportion to its length than in other species of *M* This together with the evidence of a strong prominence nea postero-lateral borders points to a genus different from any desc

MURSILIA, new genus.

The manus resembles that of *Mursia*, but lacks the crest or on the inferior margin.

Type of the genus.—*Mursilia ecristata*, new species.

MURSILIA ECRISTATA, new species.

Plate 57, fig. 27.

Type-locality.—Gatun beds. Gatun formation. Miocene Robert T. Hill, collector.

Holotype.—Cat. No. 135219, U.S.N.M.

Measurements.—Length of palm, 9.8 mm., height of palm, 7.

Represented by only one specimen showing the right palm portion of the wrist. Palm short and high. Surface finely rather distantly granulated on the upper half of the outer su and at the proximal end; more closely granulated on the lowe face. There are 9 large tubercles arranged in 3 oblique, subpa rows; the tubercle at the inferior proximal corner is much the la is flattened above and has a raised rim; between it and the tubercle in the horizontal row, but a little below, there is a s tubercle. Below the distal tubercle of the horizontal row of nearer the inner than the outer surface there is a small tubercle the upper margin there are 7 narrow, thickened teeth similar t of *Calappa*. Below the sinus between the fifth and sixth (counting from the wrist) there is a low tubercle; also one base of the second tooth. A part of a tubercle near the beginn the immovable finger is visible.

The outline of the wrist is defined, but very little of the s remains; a small piece near the distal upper corner is granulat the upper half of the palm.

The tuberculation of the manus or palm resembles that of *M* the dentation of the upper margin is nearer that of *Calappa*,

segment differs from both those genera in lacking the crest on the er margin of the palm.

Family LEUCOSIIDAE.

LEUCOSILIA JURINEI (Saussure).

Guaia (ilia) jurinei SAUSSURE, Rev. et Mag. de Zool., No. 8, 1853, p. 12, pl. 13, fig. 4.

Leucosilia jurinii BELL, Trans. Linn. Soc. London, vol. 21, 1855, p. 295, pl. 32, fig. 1.

ocality.—Panama Canal Zone. From near Mount Hope in ditch ough swampy ground. About one-quarter mile from present sea ch, 6 to 8 feet above high tide. Pleistocene series. D. F. Mac- nald, collector. April, 1911. Station 5850.

Iaterial.—Six small arm-joints more or less worn; four of them incomplete at one or both ends.

ize.—Length of a large one, 5.6 mm.

Distribution of Recent Material.—Ranges from Mazatlan, Mexico, Peru and the Galapagos Islands.

LEUCOSILIA BANANENSIS, new species.

Plate 57, figs. 6–8.

Type-locality.—Banana River, Costa Rica. Probably equivalent Gatun formation. Miocene series. D. F. MacDonald, collec- 1911. Station 5882*h*, 5*b*, 1 arm, holotype, from seventh fos- iferous zone below the uppermost one of the section. Station 5882*g*, 1 arm, paratype (*a*), from sixth fossiliferous zone below the up- most one of the section. Station 5882*f*, 3*f*, 1 arm, paratype (*b*), n fifth fossiliferous zone below the uppermost one of the section.

Types.—Cat. Nos. 324230, 324231, and 324232, U.S.N.M.

Measurements.—Length of holotype, 11.1 mm.; greatest diameter, mm.

Represented by only 3 arms from 3 different layers. The best cimen represents the left arm nearly complete, lacking only the al articulating edge.

Shape subcylindrical, slightly compressed in a vertical direction, greatest diameter being proximal to the middle, the smallest meter at the proximal end. The ornamentation consists of ercles or large granules, the granules becoming small at both ends the arm; around the middle of the segment the granules number ut 15; the tops of the granules are broken off so that they appear h flatter than they really were. Compared with *L. jurinei*, the n is more swollen, the granules less numerous, more equal and ther apart.

LEUCOSIIDAE?, genus and species indeterminable.

Plate 60, figs. 7 and 8.

Locality—Panama Canal Zone. From near Mount Hope in d through swampy ground. About one-quarter mile from present beach, 6 to 8 feet above high tide. Pleistocene series. D. F. M Donald, collector. April, 1911. Station 5850. Cat. No. 324 U.S.N.M.

Material.—Dactylus of left chela, 11.4 mm. long, with prox end lacking. This dactylus differs from those of *Persephona* allied genera in its strong curvature upwards, supposing the hensile edge to be directed inwards. This edge is nearly stra except just at the tip and is armed with 25 small unequal teeth, which in the proximal third are the largest. Besides this edge surface is composed of 4 high, smoothly rounded ridges separ by narrow grooves; 2 of the ridges are inferior, and 2 superior outermost of the latter embracing the outer edge and having a lo tudinal row of punctae near its middle. Each side of the prehe edge there are 2 or 3 rows of punctae. Tip of finger bent ra abruptly but obliquely inward, while in its upward trend it conti the curve of the rest of the dactylus.

Subtribe BRACHYGNATHA.

Superfamily BRACHYRHYNCHA.

Family PORTUNIDAE.

CALLINECTES DECLIVIS, new species.

Plate 66, figs. 1–3.

Type-locality.—Banana River, Costa Rica. Eighth fossilif zone below the uppermost one of the section. Probably equiv to Gatum formation. Miocene series. D. F. MacDonald, colle 1911. Station 5882*i; 5c.* Cat. No. 324262, U.S.N.M.

Measurements.—Greatest height, 14 mm.; length of manus m ured horizontally from extreme base of proximal spine, 21 m thickness, 9.2 mm.

Holotype.—The propodus of the left cheliped, with the tip o finger broken off. The palm is prismatic as in recent speci *Callinectes*, with 7 facets, more or less distinct; 4 facets on the surface and 3 on the inner surface. The surface, or what remai it, is smooth and shining to the naked eye, but under a lens, s very fine granulation, and larger scattered punctae. The facet separated by blunt ridges; one facet is a little above the midd

outer surface, and has subparallel margins; the facet below this ens distally and its lower edge, not very prominent, is continued n the finger, where it is sharper; the lower facet of the outer sur- is not sharply marked; the facet above the middle narrows ntly toward either end and has raised margins; at its proximal there is the stout base of a large spine such as exists in *Callinectes* ne present day. The upper facet of the inner surface is narrow, er in the middle than at the ends, and is not depressed, its distal r corner only is visible when the manus is viewed externally; ne distal end just outside the inner margin is an indication that ine has been broken off. The remainder of the inner surface is ded into 2 facets of nearly equal width separated by a prominent e.

ne finger is a little curved inward; on the outer and inner sur- there are 2 grooves, each with a row of large punctae, the groove ne middle of each surface being deeper than that near the pre- ile teeth. The teeth are of moderate size, irregular, the larger alternating with one or two smaller ones; at the broad proximal of the cutting edge there are 2 small teeth side by side, one near nner the other near the outer surface.

his propodus differs from those of all the Recent *Callinectes* in osition of the uppermost facet. In *C. sapidus*, etc., this facet is rt of the outer series, that is, continues the slope of the adjoining on the outer surface; while in the fossil it inclines downward rd the inner surface except at the distal end where it is nearly zontal. Furthermore, the propodus is shorter in proportion to eight than in recent *Callinectes*.

have placed this species in *Callinectes* rather than in *Portunus* =*Neptunus* of authors) because the palm is nearer the shape of *nectes* than it is to similar segments in the genus *Portunus*, as *nguinolentus;* the fossil is very unlike any *Portunus* now living he coast of tropical America.

CALLINECTES RETICULATUS, new species.

Plate 66, figs. 5–7.

pe-locality.—Panama Canal Zone. Las Cascadas section, Gail- Cut. From lowest fossiliferous bed; third bed below lowest tone beds separated by rows of nodules. Lower part of upper of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6020*a*. Cat. No. 31, U.S.N.M.

asurements.—Greatest height of manus, 15.6 mm.; length of s measured horizontally on middle of outer surface, 19.2 mm.; ness, 10 mm.

Holotype.—The propodus of the right cheliped, the immo
finger being broken off near its middle.

In shape, this hand is shorter, higher, and thicker than the
ceding. The surface, aside from the ridges and the uppermost
is covered with a fine reticulation of transverse grooves. The
are 7 in number and in position are like those of *C. declivis*, ex
ing that the narrow uppermost one which appears to belong t
inner surface in *C. declivis* is more horizontal in *C. reticulatus*
forms the upper surface of the segment. The next facet on the
side is narrowest at the distal end and widens to the middle,
which the margins are subparallel; the next facet widens dis
and the next also, but in a lesser degree; the lower facet is ill de
The 2 facets of the inner surface are subequal and widen distall

There is the base of a tooth at the inner distal end of the u
facet, and a short blunt spine at the distal end of the crest bet
the upper and middle facets. If there was a tooth at the pro
end it is broken off.

The propodal finger bears on its upper edge the stumps of 3
equal teeth; nearer the palm on the same surface there are 2
acute tubercles transversely placed, the inner one the larger.

Aside from the difference in shape and ornamentation betwee
species and the preceding, there is a difference in the form o
facets which may be seen by comparing figures 5 to 7 with 1 to
plate 66.

CALLINECTES, species.

Plate 65, figs. 1 and 2.

Locality.—Panama Canal Zone. From the 4 feet of dark, s
fied tuff and clay immediately overlying the lower limestone
Las Cascadas section. Upper part of Culebra formation. O
cene series. D. F. MacDonald and T. W. Vaughan, colle
1911. Station 6019*b*. Cat. No. 324255, U.S.N.M.

A specimen of a left manus and carpus, very much worn, the
and lower margins and the distal end of the manus being la
The palm is narrower than in *C. reticulatus* described above
facet near the middle of the outer surface is wider than in *C. de*
and widens distally instead of having subparallel margins as i
species.

CALLINECTES, species.

Plate 65, fig. 7.

Locality.—Panama Canal Zone. From top part of limy sand
below upper conglomerate, near foot of stairs, Gaillard Cut.
part of Culebra formation. Oligocene series. D. F. MacD

T. W. Vaughan, collectors. 1911. Station 6012*c*. Cat. No. 38, U.S.N.M.

ie distal third of the immovable finger of a claw of a *Callinectes*. he prehensile edge is shown the most distal of the large teeth mary in the genus followed (toward the tip) by 3 smaller teeth; ip is defective, having been broken off, then reattached in the g place. There is a punctated groove down the middle of the and the outer surface.

the species of *Callinectes* living on the Pacific coast of America, fragment resembles most *C. toxotes* Ordway,[1] which occurs from St. Lucas to Peru.

ARENAEUS, species.

Plate 64, fig. 1.

cality.—Panama Canal Zone. From near Mount Hope in ditch igh swampy ground. About one-quarter mile from present sea n, 6 to 8 feet above high tide. Pleistocene series. D. F. Mac-ld, collector. April, 1911. Station 5850. Cat. No. 324252, N.M.

terial.—Five fingers worn and more or less incomplete. Prob- all are movable fingers or dactyli. Length of most perfect men, 8.2 mm. On the outer surface there are two grooves dotted minute punctae; one is shallow and near the prehensile teeth, other is above the middle of the segment; on the upper surface e are also two punctated grooves, but near together, while the r surface has two furrows similar to those of the outer surface. e or four of the prehensile teeth are enlarged as is usual in unids, and the tip is curved downward. There are evidences of granulation on the uppermost ridges and on the proximal part ie segment.

his is near *A. mexicanus* (Gerstaecker[2]), a Recent species which rs from the west coast of Mexico to Peru. The shape, curvature, granulation are similar, but three of the six grooves belong defi-y to the outer surface.

EUPHYLAX CALLINECTIAS, new species.

Plate 65, figs. 3–6.

ype-locality.—Banana River, Costa Rica; ninth fossiliferous zone w the uppermost one of the section. Probably equivalent to Gatun nation. Miocene series. D. F. MacDonald, collector. 1911. tion 5882*j*; 5*d*. Cat. No. 324234, U.S.N.M.

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[1] ston Journ. Nat. Hist., vol. 7, 1863, p. 576.

[2] *ctenota mexicana* Gerstaecker, Arch. für Naturg., vol. 22, pt. 1, 1856, p. 131, pl. 5, and 4.

Measurements.—Length of carapace, 45 mm.; gastro-cardiac sut
9.6 mm.

Holotype.—One male specimen, showing parts of the upper
lower surfaces, but no appendages. The outer layer of the shel
the carapace remains only in the central part, where the gas
branchial and cardiac regions meet. This surface is granulated
areolated much as in *Callinectes;*[1] that is, the regions are separ
by definite depressions, the gastro-cardiac groove is transverse, t
is an areola at the inner angle of the branchial region, but there
shallower division into 2 lobules than in *Callinectes.* The p
gastric area is incomplete anteriorly, so that it is impossible to
whether it is marked by a raised and granulated margin; the sl
of this area most nearly resembles that of *C. exasperatus* (
staecker[2]), and its granulation that of *C. bocourti* A. Milne Edw
the granules being absent or sparse along the lateral and poste
borders. Across the middle of the gastric region runs a blunt el
tion, concave forward. The branchial region is divided in tw
a depression running obliquely backward and outward. These
two features suggest the carapace of *Euphylax dovii* Stimpso
species now existing on the Pacific coast of America, between Ce
America and Payta, Peru.

Anterior margin very broad, as in *E. dovii*, most of it b
occupied by the orbits; the front is narrow, T-shaped, much
stricted at base; the anterior part of the T has a concave su
and is deflexed to meet the epistomial spine. This is more adva
than the front; its tip is broken off. The upper margin of
orbit slopes backward and outward and is somewhat undula
The shape of the orbit can not be definitely made out, but a po
of the smooth inner lining of the outer extremity remains.
indications are that the eyestalk is long and the corneal extre
large, as in *E. dovii.*

The sternum and abdomen resemble those of *E. dovii*, the ant
end of the sternum is depressed, the depression having a co
posterior margin, from which a furrow leads back to the abdo
Surface of sternum and abdomen covered with large and di
punctae. Abdomen broadly triangular: first segment not
tinguishable; second, third, and fourth segments each crossed
transverse ridge; third, fourth, and fifth fused, and perhaps als
second with them. The sides of the penult segment are less
vergent than in *E. dovii.*

This species in all the characters visible in the type-specime
sembles the genus *Euphylax* as typified by *E. dovii*, excepting i

[1] Proc. U. S. Nat. Mus., vol. 18, 1896, pls. 12–23.
[2] Arch. f. Naturg., vol. 22, pt. 1, 1856, p. 129.
[3] Ann. Lyc. Nat. Hist. N. Y., vol. 7, 1860, p. 226, pl. 5, fig. 5.

lation and ornamentation of the central part of the carapace h indicate an affinity with *Callinectes*.

EUPHYLAX FORTIS, new species.

Plate 64, figs. 11–13.

ype-locality.—Banana River, Costa Rica; tenth fossiliferous zone v the uppermost one of the section. Probably equivalent to n formation. Miocene series. D. F. MacDonald, collector. ber, 1911. Station 5882*k*. Cat. No. 324233, U.S.N.M.

easurements.—Length of body (approx.), 43.5 mm.; length of able finger, 27.3 mm.; width of the sternum between the coxae e chelipeds, 24.5 mm.

olotype.—One specimen showing a part of the lower surface the right cheliped. The abdomen resembles that of an imma- female or is possibly that of a male.

ernum broad, surface rough with coarse punctae and fine reticu- g lines; anterior part depressed and with a median groove lead- back to the abdomen much as in *E. callinectias;* the ridge just ont of the abdomen is more transverse than in that species.

bdomen broadly triangular; it is impossible to tell which seg- s, if any, are fused; terminal segment subequilateral; surface xth and seventh segments like that of the sternum, of fourth ifth segments covered with a low, confluent granulation.

hium of external maxilliped with a longitudinal groove, the ce on the inner side of the groove more raised than on the side.

eliped elongate. A cross section of the arm is shown and a on of its lower surface; this last has a broad longitudinal de- ion through the middle, and the surface near the margins, at is coarsely granulate.

e general outline of the fingers can be made out and the sur- of some of the prehensile teeth. The fingers are elongate, as e usual Portunid, and gradually taper, ending in slender black which cross each other. The prehensile teeth are large, thick, colored, and very irregular, the one at the base of the dactylus the largest; they appear to fit close together. The cheliped ger and stronger in proportion to the size of the body than in ecent species of Portunid.

e generic position of this species is problematical; in the width e sternum it resembles *Euphylax;* in the strong teeth of the it approaches *Scylla*, while the groove on the lower side of the oint is unique.

GATUNIIDAE, new family.

Characters of the type genus, *Gatunia*.

GATUNIA, new genus.

Carapace of the customary Cancrid outline, that is, transver oval, with a narrow, dentate front (between the orbits); orbits row, with a forward inclination; antero-lateral margins arcu longer than the postero-lateral, and armed with 8 teeth, inclu the orbital tooth; postero-lateral margins strongly converg Genital region very narrow. Carapace without transverse ridg

Outer maxilliped with the ischium greatly elongate, and lo tudinally grooved.

Chelipeds massive; palms thick, not flattened on the inner devoid of ridges on the outer side.

Last pair of feet with the propodus and dactylus flattened broadened to form a swimming organ as in the Portunids.

Abdomen of the male with the third, fourth, and fifth segm fused.

This genus resembles the family Cancridae in the form of carapace, front and orbits; while the swimming paddles and th domen are like those of the Portunidae. The chelipeds appr those of the genus *Scylla* in their massiveness, long fingers and of costae, but the absence of spines gives them the appearanc many of the Xanthidae.

Type of the genus.—*Gatunia proavita* Rathbun.

GATUNIA PROAVITA, new species.

Plates 54–56; plate 58, figs. 16 and 17.

Type-locality.—Gatun formation, near Gatun Dam, Panama C Zone. Miocene series. Collected by one of the workmen shipped by D. F. Macdonald. Station 5659. One specimen (type), nearly complete. Cat. No. 324289, U.S.N.M.

Measurements.—Length of carapace, from tip of submedian t 133.2 mm.; from median sinus, 128.3 mm.; width, between tip teeth of posterior pair, 182.5 mm.; width between teeth of pe mate pair, the same.

Holotype.—Carapace about $1\frac{1}{3}$ times as wide as long; antero-l margin strongly arched, cut into 7 strong teeth, besides the at the outer angle of the orbit; teeth similar in shape, having a c posterior and a concave anterior margin, tip acute; the 7 teet crease in size from the first to the fifth and then diminish t

nth, which is the most spiniform. The orbit has a strong tooth
ıe outer and at the inner angle and one less prominent between;
w the inner angle there is a narrow tooth more advanced than
e above. Frontal region, between the orbits, with a concave
al surface; anterior border cut into 4 teeth, those of the middle
nearer to each other than they are to those of the outer pair, and
rated by a shallower sinus; teeth of inner pair oblong, with
ded end; those of outer pair thicker. Postero-lateral margins
ly straight; posterior margin slightly convex and thickened.
ırface covered with a pavement of fine, flattened granules, and
ı less numerous and unequal punctae visible to the naked eye.
depression between the gastric and branchial regions is well
ked except anteriorly, the hepatic region not being defined.
ital region very narrow, longer than wide. Cardiac and intestinal
ons incompletely outlined.
either the eyes nor the antennae are visible.
pistome subtriangular, prolonged downward at the middle in an
e angle; thence a small button-hole groove runs obliquely back-
d. Palatal ridge strong except anteriorly where it is low and
t. Pterygostomian region granulate, densely so near the buccal
ty. On the sternum a furrow runs obliquely forward from the
e of the chelipeds to the median line.
he abdomen of the male is broad and at the base reaches to the
e of the last pair of feet; there is only one segment visible be-
n the carapace and the third segment; it is probably the second,
e the first is hidden under the carapace much as in the Portunid
ıs *Callinectes;* the second is of nearly even length throughout
width; the third, fourth and fifth are fused, but their extent is
cated by indentations in the lateral margins and by a short groove
he middle; the 3d segment is produced sideways beyond the
nd 4th and its margins are very convex; margins of the 4th to
segments, inclusive, taken together are slightly convergent, those
ıe 4th a little convex; 6th segment about $1\frac{3}{4}$ times as wide as long;
ınal segment nearly as long as the preceding, subtriangular, end
ıded.
helipeds very stout, in general smooth, there being no ridges nor
es. The surface is finely granulate and punctate, the granules
tle higher than on the carapace. The inferior, anterior margin
he only margin of the merus visible; it is smoothly rounded.
pus massive, with a broad tooth at inner angle. Chelae unequal,
k, broadly rounded above and below without marginal lines;
t or larger manus about $1\frac{1}{4}$ times as long as high, left or smaller
us about $1\frac{1}{3}$ times as long as high; next the articulation of the
er palm with the dactylus there is a large lobe or tooth directed
ırd the end of the dactylus, as in *Scylla.* The digits each have 2

longitudinal punctate impressions on the outer surface, the la dactylus is more arched than the smaller; the fingers cross other a little before the tips, at least in the smaller chela; the of the larger immovable finger is broken off; prehensile edges a with large irregular, separated teeth, the basal tooth of the la dactylus being of enormous size and directed obliquely back as in *Scylla*. The distal half or two-fifths of the fingers is d colored, also the prehensile teeth.

The 3 pairs of ambulatory legs are only partially preserved; would, if extended, reach about to the middle of the manus o chelipeds; the first five segments are stout; the propodus, of w only impressions exist, has a groove through the middle and app to be flattened; the dactylus can not be made out with any degr certainty; the swimming-feet, or those of the last pair, are broad, the carpus is as broad as long; the propodus is about t as long as broad; the dactylus is lanceolate-oval, about 2⅓ tim long as broad.

Another specimen (paratype *a*) lacking the dentate border o carapace, and all appendages except the coxal joints of the legs. taken from the Gatun formation, Gatun Locks, by D. F. MacDo May, 1911. Station 5900. Cat. No. 324241, U.S.N.M.

A much smaller specimen (paratype *b*) which is identifie probably belonging to this species is labeled: "Near Gatun. cene. Rev. G. Rowell. Cat. No. 113706, U.S.N.M." It is prob from the Gatun formation. A portion of the left side of the ca pace is preserved, showing the base of the 3 posterior of the an lateral teeth; on the under side is shown the margin of the bu cavity, fragments of a maxilliped and the base of the cheliped A separate specimen (paratype *c*), from the same locality, is the left manus, somewhat crushed, proximally incomplete and lacking the propodal finger, but with the base of the dactylus attached, inclu ng the first or large, rounded tooth.

A fragment of a finger bearing 3 teeth (paratype *d*) is ref red here; the smooth outer layer is almost gone except a few bits ear the teeth; it was taken from the 85-foot cut on north side o big swamp on relocated line of the Panama Railroad, 1½ to 2 mile be yond Camp Cotton toward Monte Lirio; Gatun formation; Mio ne series; D. F. MacDonald and T. W. Vaughan, collectors, 11; Station 6030; Cat. No. 324242, U.S.N.M.

I refer here with doubt a curved fragment of a thick-shelled sp ies which has a large tooth occupying half its surface. It may be ng near one of the articulations. It was taken at Station 6033*b*, in the upper part of the lowest bed, Gatun section; Gatun forma on; Miocene series; MacDonald and Vaughan; 1911; Cat. No. 32 86, U.S.N.M.

he larger claw of this species is strikingly like that described by Milne Edwards[1] under the name *Scylla michelini* from Sceaux, Doué, France, in the Miocene shell deposits of the shell-marl Anjou. M. Milne Edwards founded the species on the claw alone. s very likely congeneric if not conspecific with the form here ribed.

Family XANTHIDAE.

CARPILIUS, species.

Plate 58, fig. 22.

ocality.—Panama Canal Zone. Foraminiferal marl and coarse lstone about 200 yards south of southern end of switch at Bohio ge station, relocated line Panama Railroad. Upper part of ebra formation. Oligocene series. D. F. MacDonald and T. W. ghan, collectors. 1911. Station 6025. Cat. No. 324243, U.S.N.M.

aterial.—Piece of propodal segment of ambulatory leg on left of crab. Length 17 mm., greatest width 7.2 mm., least width nm., proximal thickness 4.5 mm., distal thickness 3.7 mm. Viewed sally, the anterior margin is slightly convex, the posterior faintly ave. Viewed edgeways, the upper surface is longitudinally con- and the lower surface concave. Cross section oval. Surface, pt for accidental breaks, smoothly rounded, without ridges, ows, or tubercles.

n its smoothness and general form, resembles the propodus of the ambulatory leg of *Carpilius corallinus* (Herbst[2]), for which on I venture to attach the name *Carpilius* to this fragment.

HETERACTAEA LUNATA (Milne Edwards and Lucas).

Plate 63, figs. 7–9.

Pilumnus lunatus Milne Edwards and Lucas, d'Orbigny's Voy. Amér. Mér., vol. 6, 1843, p. 20; vol. 9, atlas, 1847, pl. 9, fig. 2.

ocality.—Costa Rica: City of Port Limon. Port Limon forma- . Pliocene series. Dr. L. A. Wailes, collector. Station 4269. . No. 324265, U.S.N.M.

istribution.—Recent, San Diego, California, to Chile.

aterial.—One specimen showing distal portion of outer surface larger palm, with proximal half of dactylus (showing all sur- s) attached. This must have belonged to a small individual carapace about 15 mm. wide. The fossil is crushed and the of the tubercles are lacking. The shape of the two segments so

[1] Histoire des Crustacés podophthalmaires fossiles, Paris, 1861, p. 136, pl. 3, figs. 3, 3A.
[2] Naturg. d. Krabben u. Krebse, vol. 1, 1783, p. 133, pl. 5, fig. 40.

far as it is preserved accords with that of recent specimens; h dactylus is more deflexed than it could be if the immovable fi were preserved *in situ*. The tubercles of the palm are arra in general as in recent individuals, and slight divergences are att table to individual variation. The dactylus has 6 punctated gro and the prehensile tooth situated at a little distance from the ba present; the three uppermost ridges bear some tubercles, the ridge two tubercles, the upper one three tubercles, and the inner one tubercle followed by several crenulations.

PANOPEUS ANTEPURPUREUS, new species.

Plate 58, figs. 3–11.

Type-locality.—Panama Canal Zone. From near Mount Ho ditch through swampy ground. About one-fourth mile from pr sea beach, 6 to 8 feet above high tide. Pleistocene series. I MacDonald, collector. April, 1911. Station 5850.

Types.—Cat. No. 324245, U.S.N.M.

Material.—18 dactyli of stronger chela from right side; 9 d of stronger chela from left side; 4 dactyli of weaker chela fro side; one propodal finger of weaker chela from right side.

With one exception these digits belonged to small individuals th exception, a right dactylus 12.8 mm. long, is made the holotype.

The dactyli are very much like the corresponding parts *purpureus* Lockington,[1] a recent species ranging from Lower Cali fornia to Peru. The only differences are as follows: The finge a little longer, slenderer, and straighter; the large basal tooth stronger chela is closer to the articulation with the manus; there coarse granulation on the basal portion of the dactyli, as there the living form. Most of the specimens are purplish-blue exce the tip.

The propodal finger also is slenderer than in *P. purpureus* th lower groove of the outer surface is nearer the lower margin. A thi finger was not attached to a dactylus, one cannot be positive t belongs to the same species as the dactyli.

PANOPEUS TRIDENTATUS, new species.

Plate 58, figs. 12–15.

Type-locality.—Panama Canal Zone. From near Mount Ho ditch through swampy ground. About one-quarter mile from p sea beach, 6 to 8 feet above high tide. Pleistocene series. MacDonald, collector. April, 1911. Station 5850.

Types.—Cat. No. 324244, U.S.N.M.

[1] Proc. California Acad. Sci., vol. 7, 1876 (1877), p. 101.

Material.—Eleven dactyls and three propodal digits of the right la, all detached. One of the dactyls is made a holotype.

Measurements.—Length of longest dactyl 9.2 mm., height 3 mm.; gth of holotype 6.1 mm., height 2.3 mm.

Holotype.—I have chosen a small specimen for holotype because s the best preserved. The dactyl is rather slender for the major la of a Panopeid, but it has the general character of *Panopeus* l its allies. The prehensile edge has 3 enlarged teeth, placed as lows, beginning at the proximal end: 1 l., 2 s., 1 l., 3 s., 1 l., 7 s., tip. e proximal tooth is of the customary backward-pointing type, l is of moderate size compared to the basal tooth of living Pan- ids. The second of the large teeth is of nearly the same size, re pointed, and directed downward; the third large tooth is defin- y smaller than the others. The small teeth are unequal and shal- . The longitudinal depression either side of the teeth is punc- e; there are 3 other punctate furrows, one external, one internal l the other dorsal but nearer the outer side; just within the proxi- l half of the dorsal furrow there is a marginal line of granules.

Paratypes.—The number of small teeth intervening between the ger teeth of the prehensile edge vary as follows, beginning at the ximal end: 1–3, 4–6, 6–8.

One can not be sure that the propodal digits referred here belong he same species as the dactyli. They too have 3 large teeth, which subequal and are separated by small teeth as follows, beginning h the proximal large tooth: 2, 4–5, 4–6. Proximal end broken in each case, but in one instance a small tooth is visible proximal he first large tooth. When an immovable finger is applied against ovable finger of complementary size, the large teeth of the former t into the sinuses distal to the corresponding large teeth of the er. There are 6 longitudinal punctate depressions on each pro- lus, one adjacent to the teeth on either side, one external, one in- al, and two inferior.

PANOPEUS, species.

Plate 66, figs. 8 and 9.

Locality.—From the four feet of dark, stratified tuff and clay mediately overlying the lower limestone bed. Las Cascadas sec- . Upper part of Culebra formation. Oligocene series. D. F. MacDonald and T. W. Vaughan, collectors. 1911. Station 6019½. . No. 324254, U.S.N.M.

Material.—One dactylus of right cheliped, with proximal end in- plete. Dactylus very broad at base in proportion to its length, unusually thick. Length, 9.2 mm.; width, 4.7 mm.; thickness, m. In outer view the upper margin is much curved, the surface

is much worn, but there is a line of punctae visible through the
dle; there is a large subbasal tooth directed obliquely backward,
bounded posteriorly by a deep, wide groove; the tooth does not
ject beyond the general lower margin, but it may have done so
entire. On the distal portion of the outer edge of the prehensile
face there are a few shallow crenulations.

This specimen comes nearer to *Panopeus* than to any other k
genus; from *P. chilensis* Milne Edwards and Lucas[1] it diffe
its greater width, in the large tooth originating higher up o
outer surface and in the groove behind it being deeper and
extensive.

EURYTIUM CRENULATUM, new species.

Plate 64, figs. 8 and 9.

Type-locality.—Panama Canal Zone. From near Mount Ho
ditch through swampy ground. About one-quarter mile from
ent sea beach, 6 to 8 feet above high tide. Pleistocene series.
MacDonald, collector. April, 1911. Station 5850.

Holotype.—Cat. No. 324253, U.S.N.M. Dactylus of right che
mm. long. This has the general shape of a *Eurytium* finger, b
large basal tooth of the prehensile edge is inserted higher u
oblique base running posteriorly well up on the outer surfac
tooth is directed strongly backward and is broadly rounded
extremity. It is followed by about ten low teeth, the first and
of which are the larger. Somewhat above the middle of the
and of the outer surface there is a longitudinal depression cont
a row of a few punctae. There is a deep groove on the upp
face and just within it but higher up there is a row of sep
granules or crenulations; they point outward, that is, a side vi
them may be obtained by looking down on the top of the
The ridge just outside the dorsal groove is proximally microsco
granulate.

This finger can not be referred to *E. affine*[2] or *E. tristani*[3]
Panamian fauna on account of the elevation and direction
basal tooth, and the row of granules on the upper edge.

Family GONEPLACIDAE.

Subfamily PRIONOPLACINAE.

EURYPLAX CULEBRENSIS, new species.

Plate 66, figs. 13 and 14.

Type-locality.—Panama Canal Zone. Top part of limy sa
below upper conglomerate, near foot of stairs, Gaillard Cut.

[1] D'Orbigny's Voy. Amér. Mér., vol. 6, pt. 1, 1843, p. 16; vol. 9, atlas, 1847, pl. 8,
[2] *Panopeus affinis* Streets and Kingsley, Bull. Essex Inst., vol. 9, 1877, p. 10
[3] Rathbun, Proc. Biol. Soc. Washington, vol. 19, 1906, p. 100.

of Culebra formation. Oligocene series. D. F. MacDonald T. W. Vaughan, collectors. 1911. Station 6012*c*.

olotype.—Cat. No. 324226, U.S.N.M. Propodus of right and or cheliped with only the base of the immovable finger remaining. n swollen. In side view the upper and lower margins are arcu- the palm narrowing considerably toward the wrist. Surface oth. At the distal end above the lower margin there is a deep ve which is prolonged on the finger. The palmar tooth which laps the dactylus is present; also 4 prehensile teeth of the fixed er, arranged in 2 transverse rows on the upper surface, the outer n of the distal pair being much the largest.

easurements.—Length of palm, to sinus, 6.5 mm.; height, 4.3 ; thickness, 2.7 mm.

his specimen has the general form of *E. nitida* Stimpson,[1] a Re- species occurring on the coast of the Gulf of Mexico and the Indies. I have no example of the Panamian species, *E. polita* h[2] for comparison. *E. nitida* is considerably larger than the l form, the fixed finger is somewhat wider at the base but it has basal teeth similarly disposed; the proximal end of the upper rgin is thinner and more acute than in *E. culebrensis*.

Subfamily HEXAPODINAE.

lving representatives of this subfamily are restricted to the Indo- fic region.

Genus THAUMASTOPLAX Miers.

haumastoplax MIERS, Ann. Mag. Nat. Hist., ser. 5, vol. 8, 1881, p. 261.

e generic position of the species placed here has to be deter- d by the characters discernible in a dorsal view. As in *Thau- oplax*, the shape of the carapace is subrectangular with the o-lateral corners rounded off; the second ambulatory leg is ger than the first and third. Of the other Hexapodinae, or placids with only 3 pairs of walking legs, *Hexapus* de Haan[3] re subcylindrical and has the three legs of subequal size; *Lamb- allus* Alcock[4] has smaller orbits; *Hexaplax* Doflein[5] has very ue orbits seen from above, while *Paeduma* Rathbun[6] (=*Amor- us* Bell[7]) is said to be almost cylindrical.

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n. Lyc. Nat. Hist. New York, vol. 7, 1859, p. 60.
ns. Connecticut Acad. Sci., vol. 2, 1870, p. 163.
na Japon., 1833, p. 5; 1835, p. 35.
rn. Asiat. Soc. Bengal, vol. 69, 1900, p. 329.
s. Ergeb. deutschen Tiefsee-Exped. *Valdivia*, 1898–99, vol. 6, 1904, p. 122.
c. Biol. Soc. Washington, vol. 11, 1897, p. 163.
r. Linn. Soc. London, Zool., vol. 3, 1858, p. 27.

THAUMASTOPLAX PRIMA, new species.

Plate 66, figs. 15–18.

Type-locality.—Panama Canal Zone. Las Cascadas section, G lard Cut. From lowest fossiliferous bed; third bed below lo limestone beds separated by rows of nodules. Lower part of u half of Culebra formation. Oligocene series. D. F. MacDo and T. W. Vaughan, collectors. 1911. Station 6020*a*.

Measurements.—Length of carapace, paratype, 12.2 mm. prox.); width, 18 mm. (approx.) The holotype is a little w about 19.6 mm., but the length can not be measured as the front of the carapace is not visible.

Holotype and paratype.—Carapace about 1½ times as broad as longitudinally very convex, from side to side nearly horizontal. per surface not bordered by a definite line; H-shaped depressi the center of the carapace deep; surface deeply punctate, pu crowded near the margins, sparse near the middle. Fronto-o distance about two-fifths as great as the extreme width of the pace. Antero-lateral margins long, arcuate; postero-lateral ma subparallel; posterior margin slightly convex. Front deflexed widening a little from the base of the eyestalks downward. orbit is about as wide as the narrowest part of the front and is by the eyestalk; its upper margin is transverse.

Chelipeds short, when flexed scarcely reaching beyond the end of the orbit; carpus very large, convex, smooth, and punc chela small, not much longer than carpus and considerably rower; finger shorter than palm: the end of the finger is, hov not visible. The merus of the first leg reaches quite to the e the carpus of the cheliped, its upper margin has a row of conical tubercles or granules, and there is a cluster of granules the articulation with the carpus. The merus of the secon reaches a little beyond that of the first, and is very much stro it also has a superior row of granules and a few granules o outer surface; carpus elongate, about half as long as merus: podus as wide as the greatest width of the carpus; only a p of it is visible. Third leg very much shorter and slender carpus reaching little beyond the merus of the second pair; its as well as that of the second pair, is longitudinally grooved.

The above description is made from two specimens from the place. Each specimen was enclosed in a nodule which is brok two. The holotype shows the upper surface of the carapac cept the front part), portions of the left cheliped, and of the of both sides. The nodule is not large enough to have includ whole of the legs in their extended position. Cat. No. 3 U.S.N.M. The paratype shows the carapace only; there is n

helipeds or legs; the nodule is very little wider than the carapace. No. 324228, U.S.N.M.

Family GECARCINIDAE.

CARDISOMA GUANHUMI Latreille.

Plate 64, figs. 2–4.

Cardisoma guanhumi Latreille, Encyc. Méth., Hist. Nat., Insectes, vol. 10, 1825, p. 685.

Locality.—Costa Rica: City of Port Limon. Port Limon formation, Pliocene series. Dr. L. A. Wailes, collector. Station 4269. No. 324263, U.S.N.M.

Material.—Left propodal finger of cheliped, with extremities lacking; length 18.5 mm. Pieces of the outer crust remain along the prehensile teeth, around the distal end, and on the lower part of the proximal end, where it shows the characteristic scaly granulation of the species.

Distribution of Recent Material.—From Bahamas and Florida southward to Brazil; Bermudas.

Family OCYPODIDAE.

UCA MACRODACTYLUS (Milne Edwards and Lucas).

Plate 64, fig. 7.

Gelasimus macrodactylus Milne Edwards and Lucas, d'Orbigny's Voy. Amér. Mér., vol. 6, 1843, p. 27; vol. 9, atlas, 1847, pl. 11, fig. 3.

Locality.—Panama Canal Zone. From near Mount Hope in ditch through swampy ground. About one-quarter mile from present sea level, 6 to 8 feet above high tide. Pleistocene series. D. F. Macdonald, collector. April, 1911. Station 5850. Cat. No. 324251, U.S.N.M.

Material.—A single dactylus, 6.7 mm. long, of an ambulatory leg corresponds with that of a recent specimen from Costa Rica. The dactylus is rather slender, regularly tapering and strongly curved; as concave as well as on its convex margin, it has 6 longitudinal grooves separated by as many smooth rounded ridges; toward the blunt tip these ridges are themselves guttered by a narrow groove.

Distribution of Recent Material.—From Guaymas, Mexico, to Valparaiso, Chile.

BRACHYRHYNCHA, family, genus, and species indeterminable.

Plate 64, fig. 6.

Locality.—Panama Canal Zone. Las Cascadas section, Gaillard Cut. From lowest fossiliferous bed. Third bed below lowest lime-

stone beds separated by rows of nodules. Lower part of upper
of Culebra formation. Oligocene series. D. F. MacDonald
T. W. Vaughan, collectors. 1911. Station 6020*a*. Cat. No. 32
U.S.N.M.

Material.—A specimen 9.3 mm. long and 7.7 mm. wide, whic
sembles the proximal part of the right manus of a crab. The oute
lower surfaces are exposed, but the outer layer of shell has almos
appeared. The surface gradually ascends to a line a little belov
middle where a blunt longitudinal ridge is formed. Just belov
upper margin, and also just within the lower margin on the
side, there is a narrow furrow.

The blunt crest is suggestive of the Portunidae.

BRACHYRHYNCHA, family, genus, and species indeterminable

Plate 64, fig. 5.

Locality.—Panama Canal Zone. Las Cascadas section, Ga
Cut. From lowest fossiliferous bed. Third bed below lowest
stone beds separated by rows of nodules. Lower part of upper
of Culebra formation. Oligocene series. D. F. MacDonald
T. W. Vaughan, collectors. 1911. Station 6020*a*. Cat. No. 3
U.S.N.M.

Material.—Two specimens, each embedded in a nodule, of a
ment which appears to be the merus segment of an ambulato
of a crab. The surface is flat, the lateral margins are arcuat
there is a shallow longitudinal depression near one edge. The
is very suggestive of the Portunidae and yet they do not c
resemble any known species.

Superfamily OXYRHYNCHA.

Family PARTHENOPIDAE.

PARTHENOPE PANAMENSIS, new species.

Plate 66, figs. 10 and 11.

Type-locality.—Panama Canal Zone. Las Cascadas s
From fifth or topmost limestone. Emperador limestone. Oli
series. D. F. MacDonald and T. W. Vaughan, collectors.
Station 6019*g*. Cat. No. 324257, U.S.N.M.

Measurements.—Length of arm measured along lower marg
complete), 24.6 mm.; distal width, measured on inner, lower s
6.6 mm.; minimum width, on the same surface, 4.7 mm.

Holotype.—One specimen represented by only the merus j
the left cheliped. This segment is thick; a cross section is

ral and nearly as broad as long; the proximal end is broken off, distal end is embedded in a hard matrix. The two upper sur- s are each not much more than half as wide as either of the two r surfaces. The upper, inner and outer margins are armed with gular spines and tubercles, the lower margin with tubercles only, ch are not in a single row; the surfaces also have a few scattered es and tubercles. The tips of most of the spines are broken off; largest spines are one on the upper margin near the proximal end the specimen), and one just above the outer margin in the middle d. The distal extremity of the segment widens in a manner sug- ive of the propodus of a Parthenopid, but it is not triangular- matic as customary in the propodal segments.

PARTHENOPE PLEISTOCENICA, new species.

Plate 61, figs. 10 and 11.

ype-locality.—Panama Canal Zone. From near Mount Hope in h through swampy ground. About one-quarter mile from pres- sea beach, 6 to 8 feet above high tide. Pleistocene series. D. F. Donald, collector. April, 1911. Station 5850. Cat. No. 324247, .N.M.

olotype.—Propodal finger of right and major chela; lower proxi- portion missing. Lower margin, so far as it remains, nearly ight, tip upturned; upper margin broad at the proximal end armed with 5 unequal blunt teeth; the first or that nearest the n is broadly united with the second which is much larger; third imilar size and shape to the second and well separated from it; th much smaller and fifth minute. Four lateral rows of punctae, either side of the prehensile teeth, and one through the middle he inner and of the outer surface. The posterior half of both aces is sparsely covered with prominent and very unequal nules.

arthenope excavata (Stimpson)[1] of which there is an example n Panama in the United States National Museum collection has nilar prehensile surface, but the lateral face is shorter and higher is granulate all over outside.

EXPLANATION OF PLATES.

Plate 54.

Gatunia proavita Rathbun, holotype, dorsal view, × ⅔.

Plate 55.

Gatunia proavita, holotype, ventral view, × ½.

[1] *ambrus excavatus* Stimpson, Ann. Lyc. Nat. Hist. New York, vol. 10, 1871, p. 98.

PLATE 56.

Gatunia proavita, holotype.

FIG. 1. Anterior view, × ⅔.
2. Posterior view, × ⅔.

PLATE 57.

FIG. 1. Natantia, indeterminable, lateral view of pleon. × 2.
2. *Axius reticulatus* Rathbun, holotype, outer view of propodus of cheliped, × 3.
3. Impression of same.
4. *Macrobrachium*, species, Cat. No. 324256, outer view of propodus of cheliped, × 3.
5. Upper view of same.
6. *Leucosilia bananensis* Rathbun, paratype *a*, arm joint, × 3.
7. *Leucosilia bananensis*, paratype *b*, arm joint, × 3.
8. *Leucosilia bananensis*, holotype, arm joint, × 3.
9. *Macrobrachium?*, species, Cat. No. 324248, segment of large chel × 3½.
10. *Axius?*, species, Cat. No. 324250, scaphocerite, × 3½.
11. *Goniochele? armata* Rathbun, holotype, outer view of dactylus of cheliped, × 2.
12. Lower view of same, × 2.
13. *Nephrops costatus* Rathbun, holotype, dactylus of left cheliped, view, × 3½.
14. Dorsal view of same, × 3½.
15. *Nephrops costatus*, paratype *a*, dactylus of left cheliped, dorsal × 3½.
16. *Nephrops costatus*, paratype *c*, propodal finger of left cheliped, d view, × 3½.
17. *Nephrops costatus*, paratype *b*, dactylus of left cheliped, dorsal × 3½.
18. *Petrolisthes avitus* Rathbun, holotype, palm of left cheliped, dorsal × 3½.
19. Inner view of same, × 3½.
20. Ventral view of same, × 3½.
21. *Pachycheles latus* Rathbun, holotype, propodus of left cheliped, ve view, × 3½.
22. Dorsal view of same.
23. *Pachycheles latus*, paratype, left chela, dorsal view, × 3½.
24. *Calappa costaricana* Rathbun, holotype, portion of propodus of chela, outer view, × 3.
25. *Nephrops*, species, Cat. No. 324249, dactylus of right cheliped, preh edge, × 3½.
26. Dorsal view of same, × 3½.
27. *Mursilia cristata* Rathbun, holotype, right cheliped, outer view, ×

PLATE 58.

FIG. 1. *Calappella quadrispina* Rathbun, holotype, impression of carapace,
2. Carapace of figure 1, × 3.
3. *Panopeus antepurpureus*, Rathbun, holotype, dactylus of right che × 3½.

5. *Panopeus antepurpureus*, paratypes, dactyli of right chelipeds, × 3½.
Panopeus antepurpureus, paratype, immovable finger of right cheliped, × 3½.
Panopeus antepurpureus, paratypes, dactyli of left chelipeds, × 3½.
Panopeus tridentatus Rathbun, paratype, dactylus of right cheliped, × 3½.
Panopeus tridentatus, paratype, propodal finger of right cheliped, × 3½.
Panopeus tridentatus, holotype, dactylus of right cheliped, outer view, × 3½.
Upper edge of same, × 3½.
Fragment of *Gatunia proarita* ??, Cat. No. 324286, showing lobe in profile, × 2.
Flat surface of same, × 2.
Callianassa hilli Rathbun, paratype *b*, sixth segment of pleon, × 2.
Callianassa hilli, holotype, merus and carpus of right cheliped, × 2.
Callianassa hilli, paratype *a*, right cheliped, × 2.
Mursia macdonaldi Rathbun, holotype, left palm, × 2.
Carpilius, species, Cat. No. 324243, piece of propodus of a left ambulatory leg, × 2.

PLATE 59.

Callianassa ovalis Rathbun, holotype, left cheliped, × 2.
Callianassa ovalis, paratype *a*, propodus of left cheliped, × 2.
Impression of figure 1, × 2.
Callianassa ovalis, paratype *b*, carpus of left cheliped, × 2.
Callianassa, species, Cat. No. 324277, manus of left cheliped, × 3½.
Callianassa lacunosa Rathbun, holotype, left manus, distal view, × 3.
Outer view of same, × 3.
Inner view of same, × 3.
Callianassa lacunosa, paratype, left manus, inner view, × 3.
Outer view of same, × 3.
Distal view of same, × 3.

PLATE 60.

Callianassa moinensis Rathbun, holotype, propodus of right cheliped, lower view, × 3.
Upper view of same, × 3.
Outer view of same, × 3.
Callianassa elongata Rathbun, holotype, propodus of left cheliped, upper view, × 2.
5. Outer view of same, × 2.
3. Lower view of same, × 2.
. Leucosiidae?, indeterminable, Cat. No. 324136, dactylus of left chela, outer view, × 3½.
3. Upper view of same, × 3½.
). *Callianassa scotti* Brown and Pilsbry, holotype, left manus, lower view, × 1½.
). *Callianassa scotti*, paratype, Cat. No. 2259, left propodus, upper view, × 1½.
. Outer view of same, × 1½.
2. *Callianassa scotti*, Cat. No. 324279, left manus, distal view, × 1½.
3. *Callianassa tenuis* Rathbun, holotype, left manus, inner view, × 3.
. Outer view of same, × 3.

PLATE 61.

FIG. 1. *Callianassa crassa* Rathbun, holotype, dactylus of left cheliped, ...view, × 2.
2. Outer view of same, × 2.
3. *Callianassa crassa*, paratype, dactylus of left cheliped, outer view, ...
4. *Calappa flammea*, dactylus of right cheliped, inner view, × 2.
5. Outer view of same, × 2.
6. *Callianassa spinulosa* Rathbun, paratype in Mus. Acad. Nat. Sci. ... propodus of left cheliped, outer view, × 2.
7. *Callianassa spinulosa*, holotype and impression, left propodus, ... view, × 2.
8. Distal view of same holotype, × 2.
9. Inner view of same, × 2.
10. *Parthenope pleistocenica* Rathbun, holotype, propodal finger of ... chela, upper view, × 3½.
11. Outer view of same, × 3½.
12. *Callianassa stridens* Rathbun, holotype, left manus, outer view, ...
13. Upper view of same, × 3.
14. Inner view of same, × 3.
15. *Callianassa crassimana* Rathbun, holotype, propodus of left ch... inner view, × 2.
16. Impression of same, and piece of finger, × 2.
17. Holotype laid against impression of same, outer view, × 2.
18. *Mursia obscura* Rathbun, holotype, carapace, × 3.

PLATE 62.

FIG. 1. *Callianassa magna* Rathbun, holotype, dactylus of right cheliped, ... view, × 1½.
2. Outer view of same, × 1½.
3. Upper view of same, × 1½.
4. *Callianassa quadrata* Rathbun?, carpus of left cheliped, upper view, ...
5. Lower view of same, × 2.
6. Outer view of same, × 2.
7. *Callianassa quadrata*, holotype, left manus, distal view, × 2.
8. Inner view of same, × 2.
9. Outer view of same, × 2.
10. *Callianassa quadrata*, paratype *a*, left manus, outer view, × 2.
11. Inner view of same, × 2.
12. Distal view, × 2.
13. *Callianassa quadrata*, paratype *c*, right manus, outer view, × 2
14. *Callianassa quadrata*, paratype *d*, left manus, outer view, × 2.

PLATE 63.

FIG. 1. *Callianassa abbreviata* Rathbun, holotype, right manus, inner view, ...
2. Outer view of same, × 3.
3. Distal view of same, × 3.
4. Impression of same, × 3.
5. *Callianassa abbreviata*, paratype *b*, piece of propodus of left chel... outer view, × 3.

6. *Callianassa abbreviata*, paratype *a*, left manus, outer view, × 3.
7. *Heteractaea lunata* (Milne Edwards and Lucas), right chela, Cat. No. 324265, outer view, × 3½.
8. Upper view of same, × 3½.
9. *Heteractaea lunata*, right chela of Recent specimen, Cat. No. 2146, × 3½.
0. *Callianassa vaughani* Rathbun, paratype *b*, portion of propodus of left cheliped, outer view, × 2.
1. *Callianassa vaughani*, paratype *a*, left manus, outer view, × 2.
2. Inner view of same, × 2.
3. *Callianassa vaughani*, holotype, right chela, outer view, × 2.

PLATE 64.

1. *Arcnaeus*, species, Cat. No. 324252, left movable finger, outer view, × 3½.
2. *Cardisoma guanhumi* Latreille, propodal finger of left cheliped, outer view, × 3.
3. Lower view of same, × 3.
4. Upper view of same, × 3.
5. *Brachyrhyncha*, indeterminable, Cat. No. 324258, merus of ambulatory leg, × 3.
6. *Brachyrhyncha*, indeterminable, Cat. No. 324294, right manus, × 3.
7. *Uca macrodactylus* (Milne Edwards and Lucas), Cat. No. 324251, dactylus of ambulatory leg, × 3½.
0. *Callianassa?*, species, Cat. No. 324280, merus of right cheliped (?), view, × 3½.
9. Upper view of same, × 3½.
10. *Callianassa?*, species, Cat. No. 324280, merus of right cheliped (?), × 3½.
1. *Euphylax fortis* Rathbun, holotype, right side, showing cross sections of merus of cheliped and of two legs, × 1½.
2. Front view of same, showing remains of fingers, × 1½.
3. Ventral view of same, × 1¼

PLATE 65.

1. *Callinectes*, species, Cat. No. 324255, manus and carpus of left cheliped, outer view, × 1½.
2. Upper view of same, × 1½.
3. *Euphylax callinectias* Rathbun, holotype, dorsal view, × 1½.
4. Posterior view of same, × 1½.
5. Ventral view of same, × 1½.
6. Anterior view of same, × 1½.
7. *Callinectes*, species, Cat. No. 324268, distal third, tip missing, of immovable finger, × 3.

PLATE 66.

1. *Callinectes declivis* Rathbun, holotype, propodus of left cheliped, upper view, × 1½.
2. Inner view of same, × 1½.
3. Outer view of same, × 1½.
4. *Hepatus chiliensis* Milne Edwards, Cat. No. 324235, dactylus of right chela, inner view, × 3½.
5. *Callinectes reticulatus* Rathbun, holotype, propodus of right cheliped, upper view, × 1½.

FIG. 6. Inner view of same, × 1½.
7. Outer view of same, × 1½.
8. *Panopeus*, species, Cat. No. 324254, dactylus of right cheliped, u
view, × 3.
9. Outer view of same, × 3.
10. *Parthenope panamensis* Rathbun, holotype, merus of left cheliped,
view, × 1½.
11. Inner view of same, × 1½.
12. *Hepatus*, species, Cat. No. 324239, dactylus of left cheliped, outer
× 2.
13. *Euryplax culebrensis* Rathbun, holotype, propodus of right chel
upper view, × 3½.
14. Outer view of same, × 3½.
15. *Thaumastoplax prima* Rathbun, paratype, carapace, × 2.
16. Impression of same, × 2.
17. *Thaumastoplax prima*, holotype, × 2.
18. Impression of same, × 2.

GATUNIA PROAVITA RATHBUN.

FOR EXPLANATION OF PLATE SEE PAGE 179.

GATUNIA PROAVITA RATHBUN.

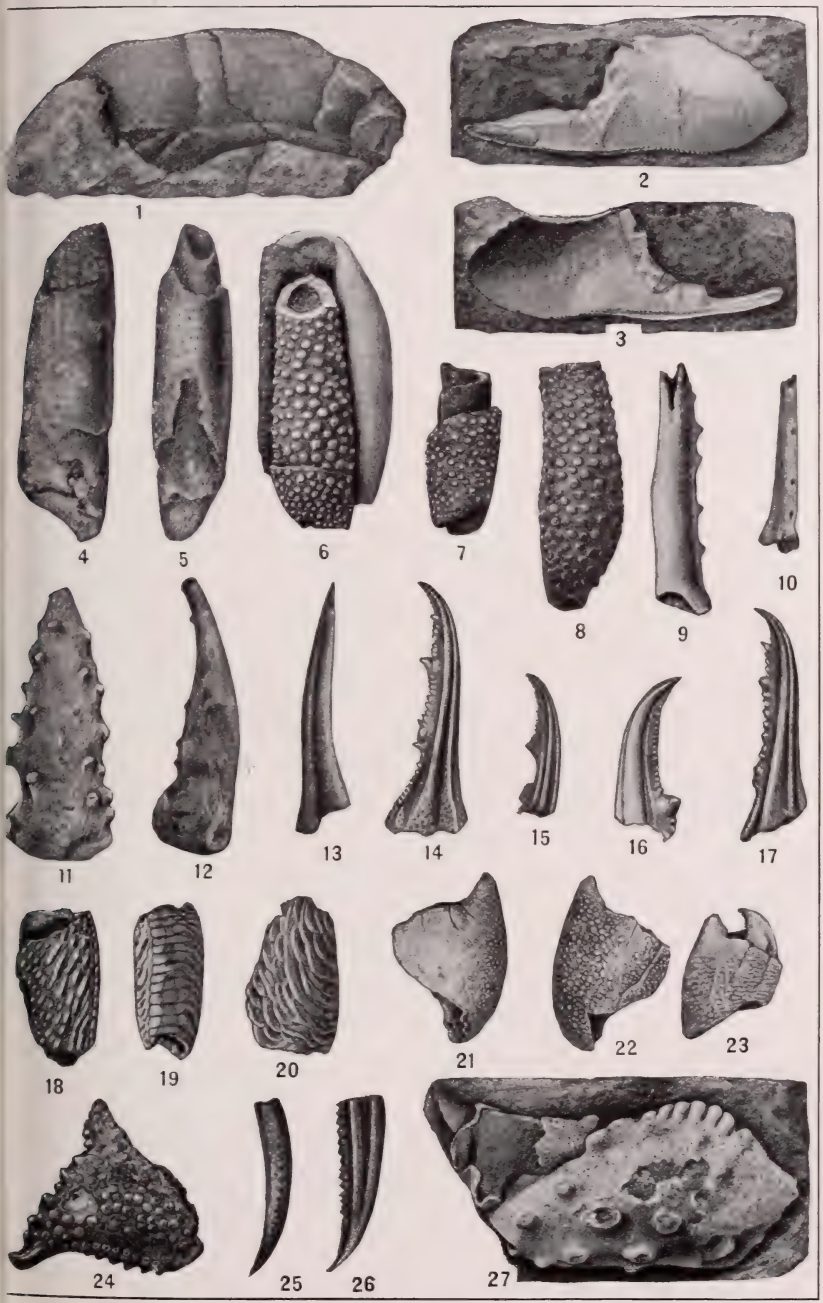
FOR EXPLANATION OF PLATE SEE PAGE 179.

1

2

GATUNIA PROAVITA RATHBUN.

FOR EXPLANATION OF PLATE SEE PAGE 180.

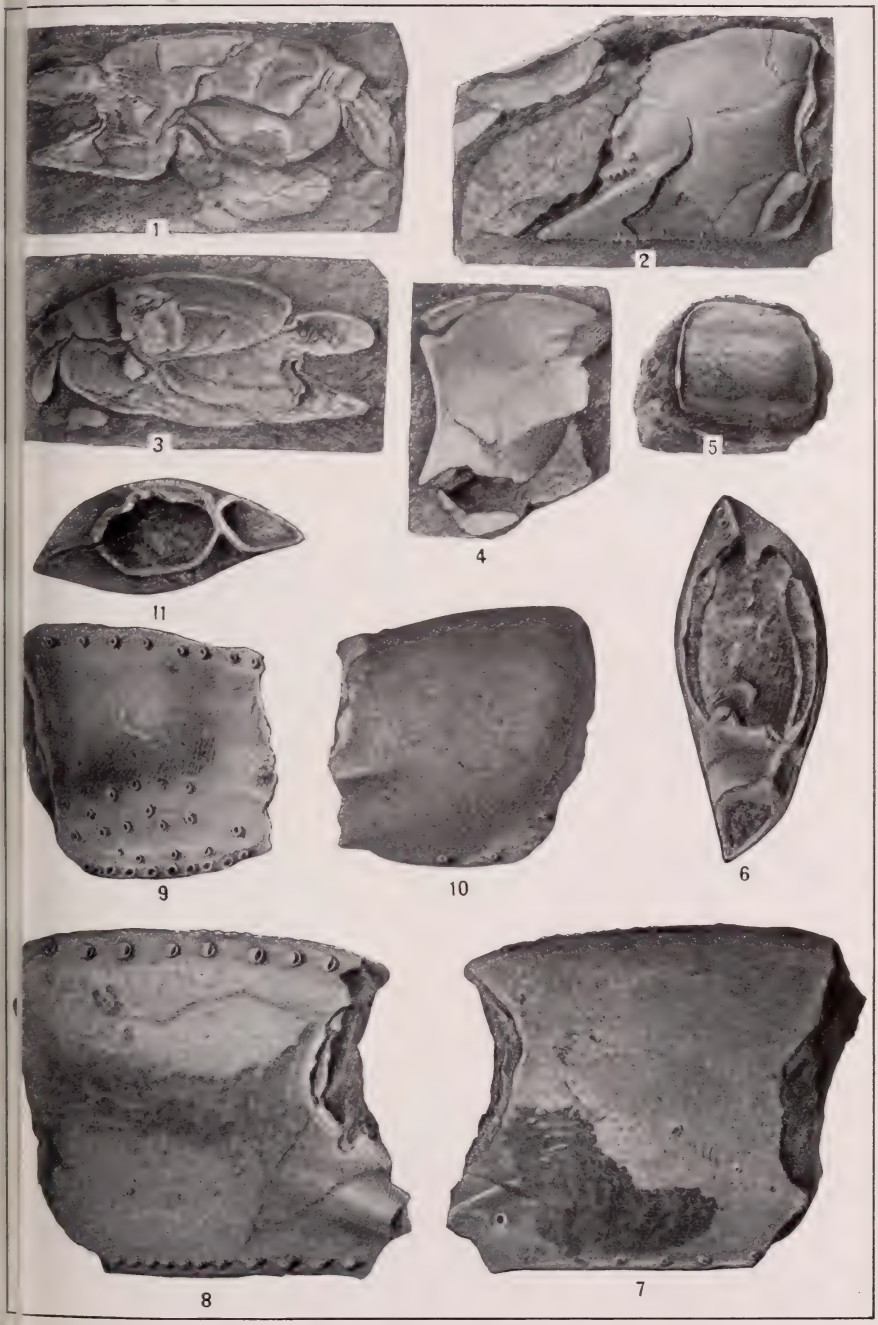


PANAMA DECAPOD CRUSTACEANS.

FOR EXPLANATION OF PLATE SEE PAGE 180.

PANAMA DECAPOD CRUSTACEANS.

FOR EXPLANATION OF PLATE SEE PAGE 180



PANAMA DECAPOD CRUSTACEANS.

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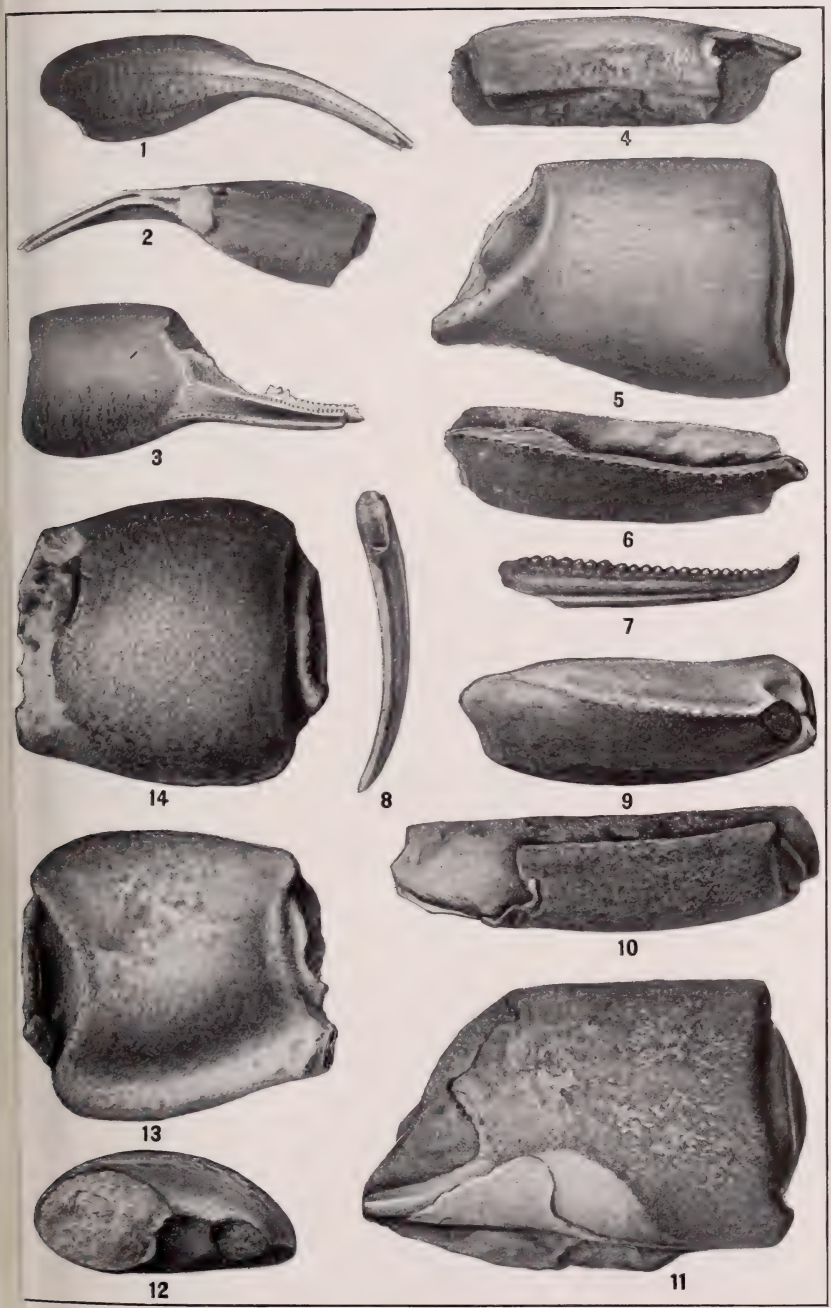

PANAMA DECAPOD CRUSTACEANS.

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PANAMA DECAPOD CRUSTACEANS.

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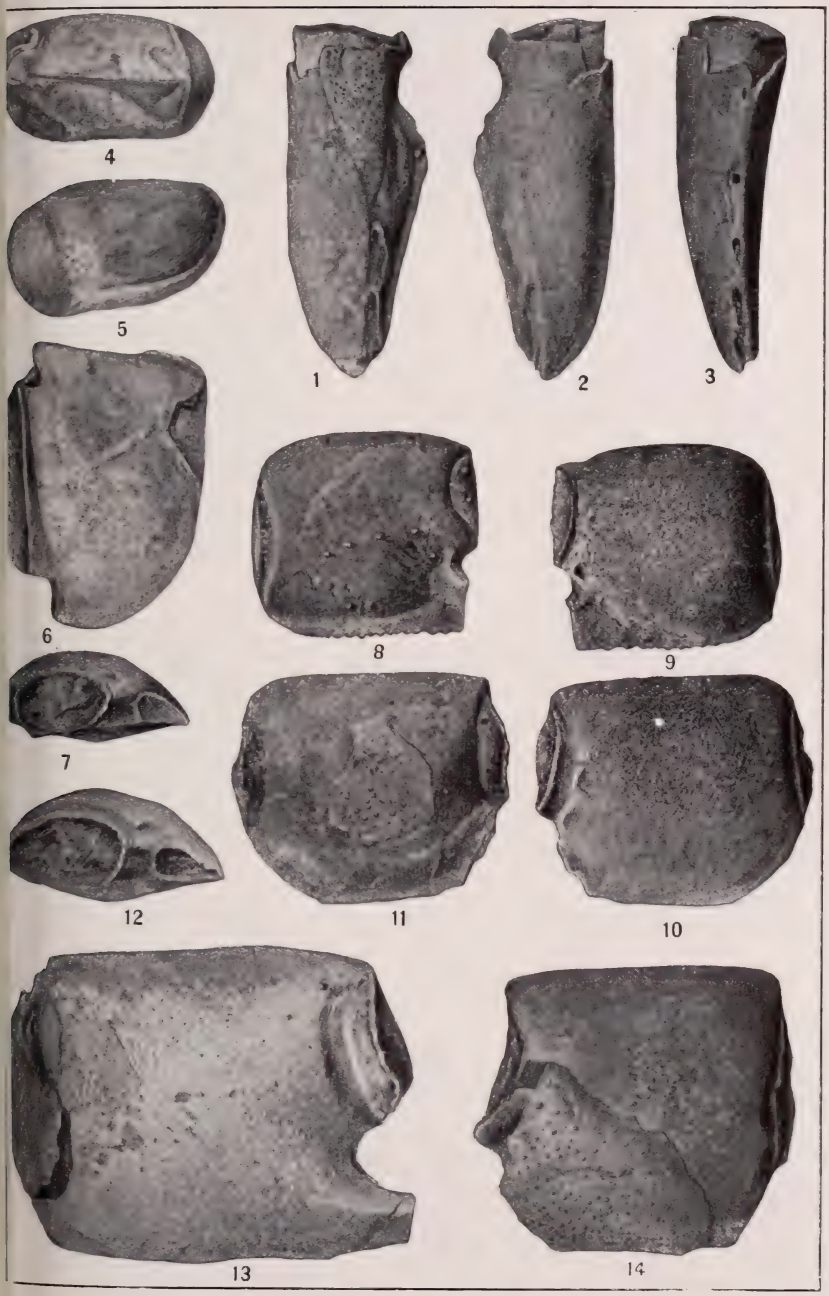

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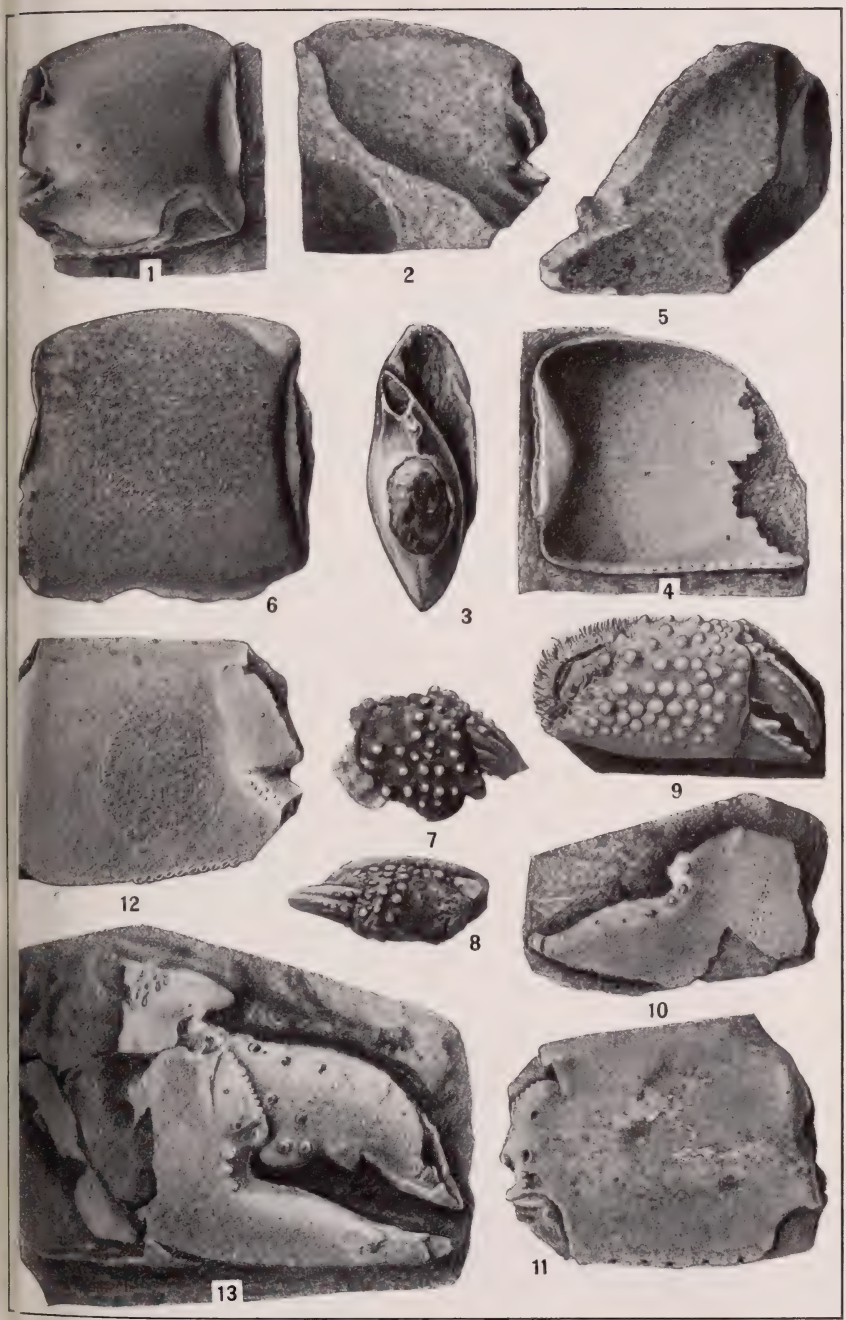

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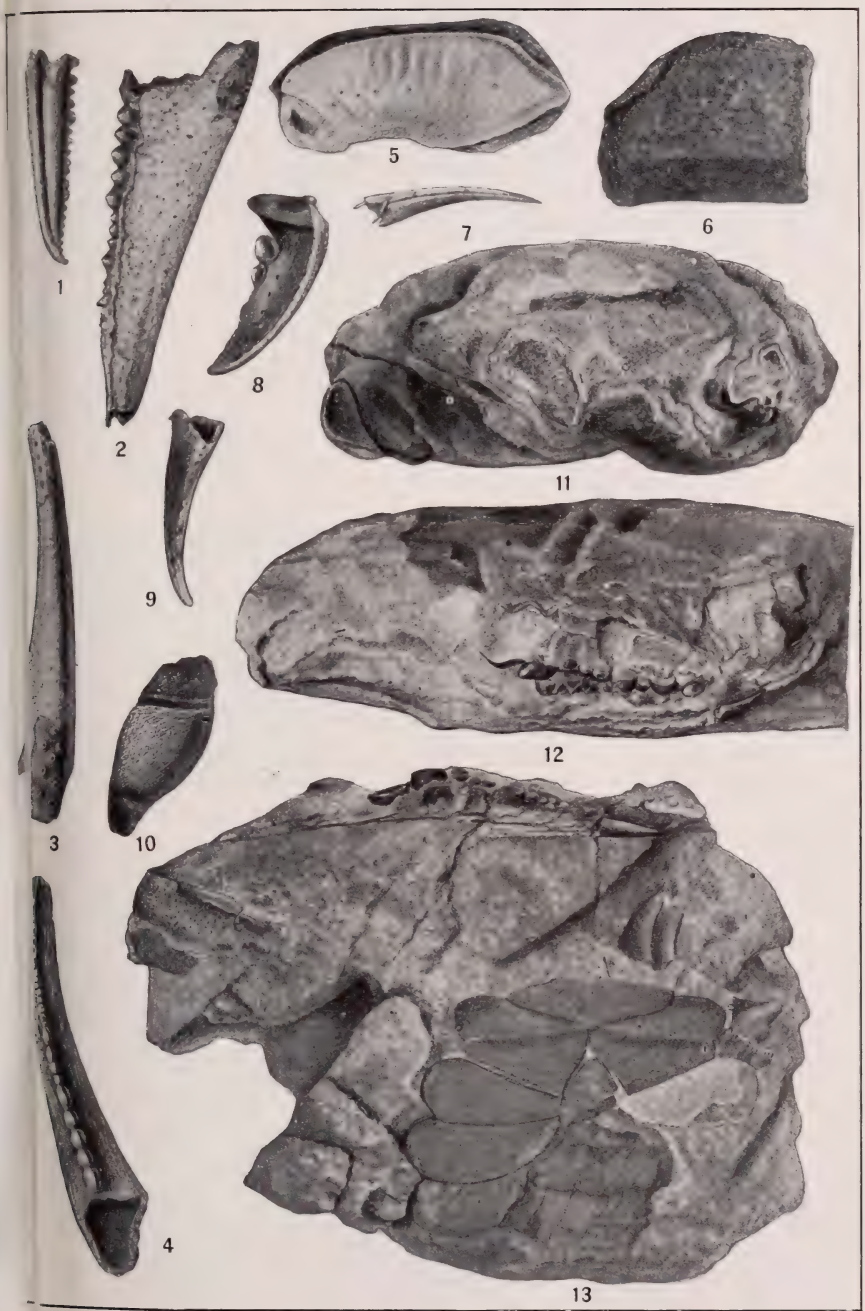
FOR EXPLANATION OF PLATE SEE PAGES 182 183.



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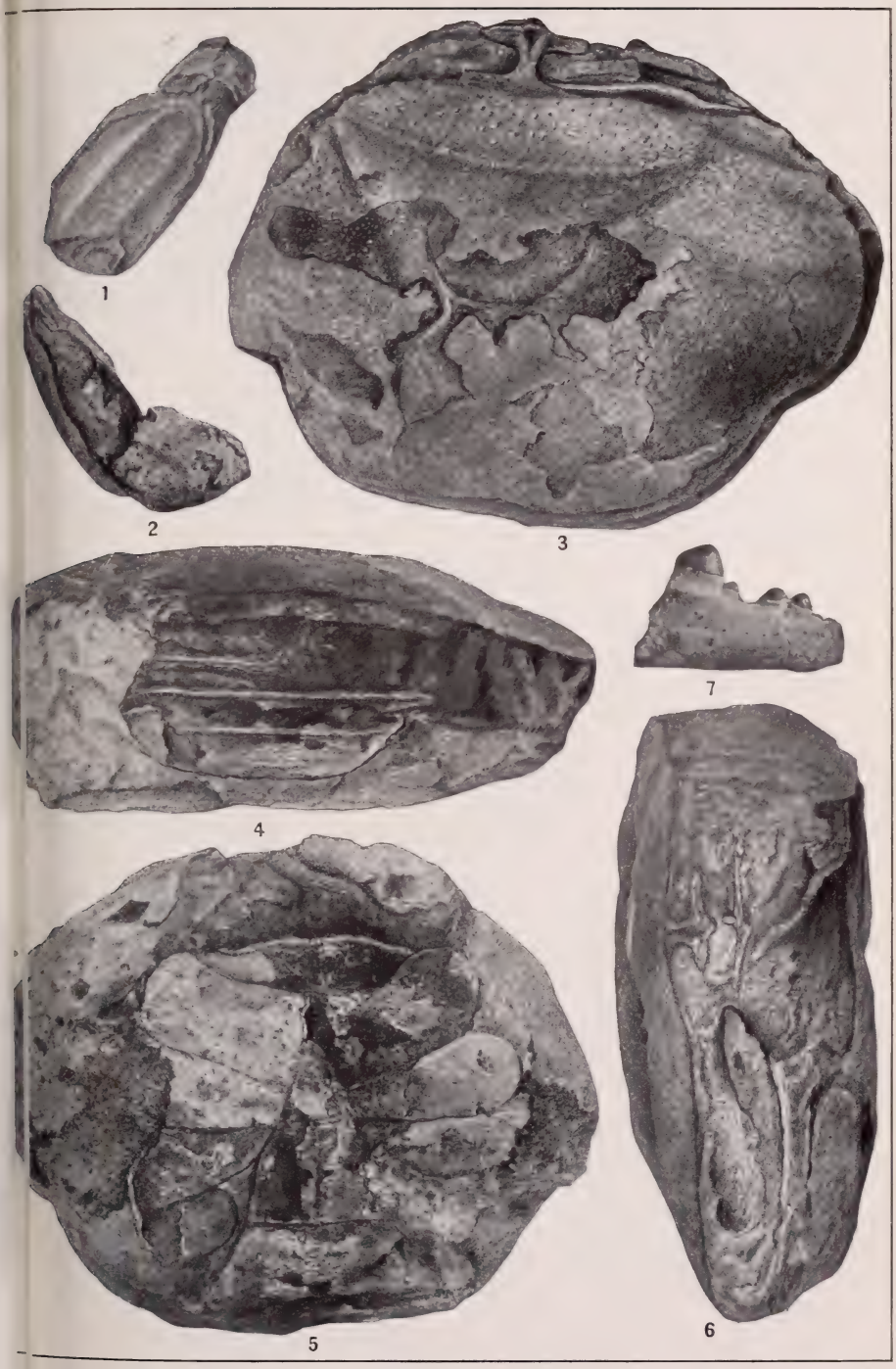

PANAMA DECAPOD CRUSTACEANS.

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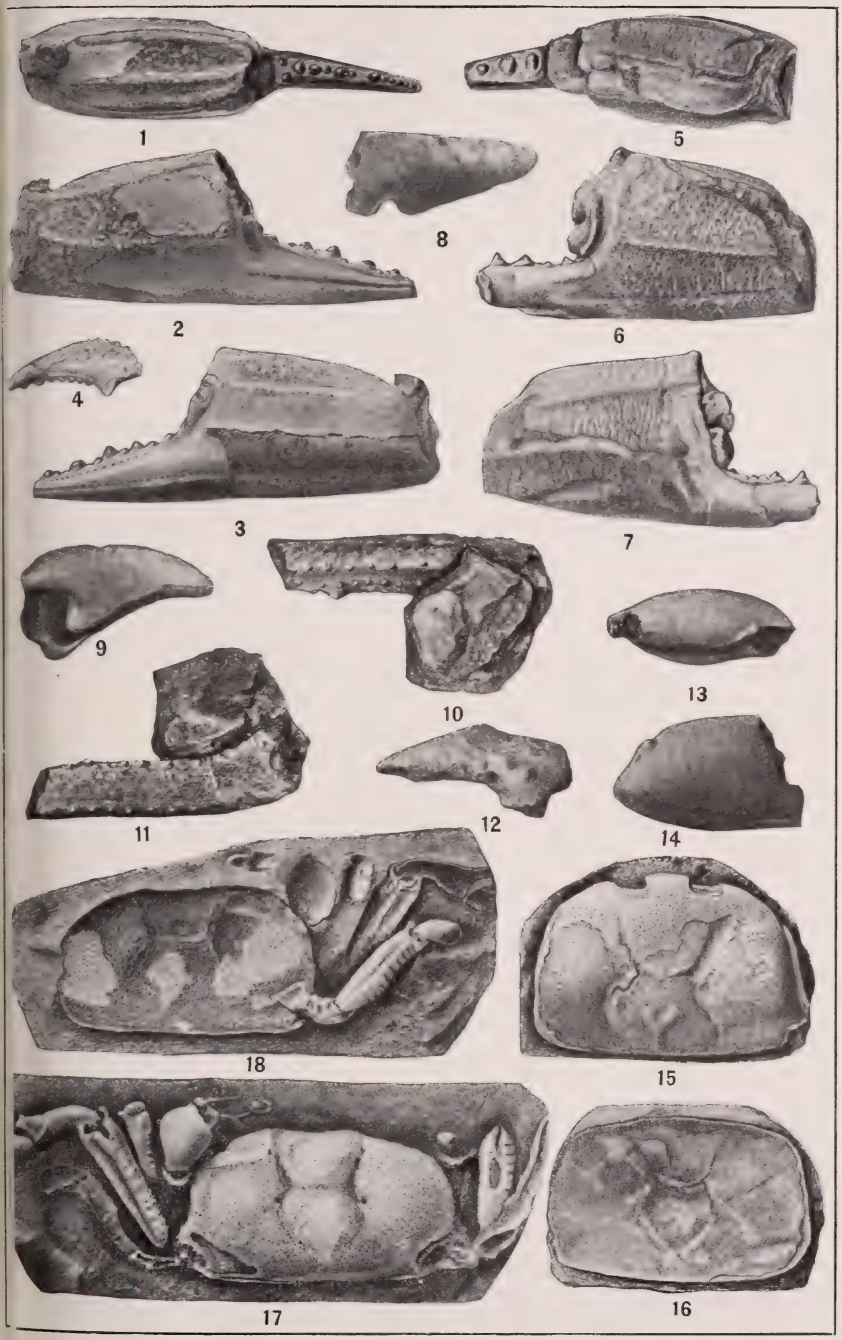

PANAMA DECAPOD CRUSTACEANS.

FOR EXPLANATION OF PLATE SEE PAGES 183, 184.

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SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

CIRRIPEDIA FROM THE PANAMA CANAL ZONE

By HENRY A. PILSBRY
Of the Academy of Natural Sciences, Philadelphia

Extract from Bulletin 103, pages 185–188, with Plate 67

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1918

CIRRIPEDIA FROM THE PANAMA CANAL ZONE.

By Henry A. Pilsbry,

Of the Academy of Natural Sciences, Philadelphia.

The small number of barnacles collected show the following relations. The Pleistocene and Pliocene species are identical with recent Pacific coast and Caloosahatchie Pliocene species, respectively, and are distinctively Atlantic forms. Of the Oligocene and Miocene species, one has relatives in both oceans, another only in the Pacific; the affinities of the third being doubtful.

BALANUS EBURNEUS Gould.

Balanus eburneus Pilsbry, Bull. U. S. Nat. Mus., No. 93, 1916, p. 80, pl. 24, figs. 1–1*c*, 2, text-figs. 14 and 15, and synonymy.

This recent species is represented by four individuals from Station 37, the wall being preserved complete, but without opercular plates. The smooth surface and the closely, regularly septate parietal tubes are characteristic, the septa forming cells about equal in length and breadth, throughout the tubes.

Locality and geologic occurrence.—They are from a dark mud formation about 10 feet above the present sea level, near lower end of Gatun Locks. Pleistocene series. D. F. MacDonald, collector. April, 1911. Cat. No. 324297, U.S.N.M. Five specimens, from Station 5868, from Mount Hope, in swamp ditch, in black mud formation; Pleistocene; D. F. MacDonald, 1911. Cat. No. 324290, U.S.N.M. Ten specimens of the same were taken at Station 6038, also from black mud fromlower end of Gatun Locks. Pleistocene series. D. F. MacDonald, collector, 1911. Cat. No. 324293, U.S.N.M.

BALANUS GLYPTOPOMA Pilsbry.

Plate 67, figs. 1–3.

Balanus concavus glyptopoma Pilsbry, Bull. U. S. Nat. Mus., No. 93, p. 102, pl. 21, fig. 2; pl. 22, figs. 2–2*c*.

The walls only of several groups growing on oysters and scallops were collected. They agree with the above species described from the Pliocene of the Caloosahatchie River, and show some additional characters, notably the color. The radii are broad. The parietes are darkly ribbed longitudinally, the intervals in the best preserved individuals being of a deep livid brown color, the low ribs white. The parietal tubes are crossed by many septa, down to the base; these are a little less regular than in *B. eburneus*, most of the cells being longer

than wide, exactly as in the type of *B. glyptopoma.* There ar tubes in the rostrum of one of the specimens figured (fig. 2). basis is profusely porous, the pores septate (fig. 3, left hand middle individuals of group shown in fig. 1). The middle speci of this group is 31 mm. high, the rostro-carnial diameter a 22 mm.

B. glyptopoma was described as a subspecies of *B. concavus* Br but it differs from that by the closely septate parietal tubes, ar evidently a distinct species. In *B. concavus* the tubes are fille near the summits, and are open, with very few septa below, or in the American subspecies. The Miocene form formerly referre *B. glyptopoma* is a distinct subspecies of *B. concavus.*

Location and geologic occurrence.—The specimens are from tion 5903, across Chagres River and about 200 to 225 feet abo top of hill opposite Alhahuela, in a gray tufaceous limestone, No. 324298, U.S.N.M. and Station 5906*a*, 50 to 75 feet below Cat. No. 324299, U.S.N.M. Both collected by D. F. MacDo Upon mentioning to Dr. William H. Dall that I had identifi Pliocene barnacle from these Stations, he kindly informed me "both are above the Oligocene strata and separated from the l by an unconformity. They are doubtless Pliocene. 5906*a* is lower of the two horizons."

Mexico. From the Sayula District of Chiapas, on the A Chapapoapam. Pliocene series. Dr. C. W. Hayes and others lectors; 1911. Station 5886. One specimen, without opercular v Cat. No. 324291, U.S.N.M.

BALANUS CONCAVUS RARISEPTATUS, new subspecies.

Plate 67, fig. 4.

In form this barnacle is somewhat cylindric with contracted mit in the adult stage, convexly conic when young. The orif ovate. The walls are only slightly roughened longitudinally. carinolateral compartments are narrow, the parietes about one- as wide as the lateral compartments. The radii are wide oblique summits, without pores; the articulating edges being lated. The parietal tubes have very few, irregularly scattered, verse septa. There are 29 tubes in the rostrum of the type-spec Another, of equal size, has 17 tubes in the lateral, 6 in the c lateral compartment.

Length, 27 mm.; carino-rostral diameter, 22.5 mm.; lateral d ter, 21 mm. In the largest individual exposed the rostrum is 3 long.

This form is represented by a group of about 16 individuals ing upon and largely concealing a single old one of about 37 basal diameter. Probably three generations are present. They

a tufaceous limestone. The tubes of the walls are solidly filled h calcite.

This was at first thought to be a smooth form of *Balanus concavus* onn, but on cutting it the parietal tubes were found to be much re numerous. In a specimen of *B. concavus* from the British Red ag (Pliocene), No. 12058, U.S.N.M., there are 19 tubes in the trum, which is 65 mm. long. Most of these tubes have transverse ta at long, irregular intervals, but in some places near the edges septa are rather close, though irregular.

The relation of this form to *B. concavus* can not be exactly esti- ted until the opercular plates are found. It may be an ancestral m of *concavus* or a distinct species. Meantime, it is readily recog- able by the characters of the compartments.

Locality and geologic occurrence.—Panama Canal Zone. From foot cut, just on north side of big swamp, on relocated line Panama ilroad, 1½ to 2 miles beyond Camp Cotton toward Monte Lirio. tun formation. Miocene series. D. F. MacDonald and T. W. ughan collectors, 1911. 1 cluster; Cat. No. 324292, U.S.N.M.

BALANUS (HESPERIBALANUS?), species.

A small, conic barnacle having a basal diameter of about 7 or 8 m. is represented by several compartments and one incomplete cimen, without opercular valves. The walls are smooth except for ght ripples parallel to the base. They are solid, having no parietal es. The compartments are rather thick for so small a barnacle, l when parted the articulating edges of the radii and the opposed ural surfaces are seen to be conspicuously crenulated. The basis calcareous, thin, and seems to have radial threads on its inner e.

These characters indicate a species of the subgenus *Hesperibalanus*, possibly *Solidobalanus*. Neither group has been recognized herto in American tertiary deposits, or in the recent faunas of the namic region or western Atlantic. The specimens do not seem racteristic enough to serve as the basis of a new species, though ly can not, I think, be referred to any described form.

Locality and geologic occurrence.—They were collected by Mac- nald and Vaughan in the "lowest fossiliferous bed, the third below lowest limestone bed, Las Cascadas section, Gaillard Cut. Lower t of upper half of Culebra formation. Oligocene." Station 6020*a*, . No. 324295, U.S.N.M.

A single valve was taken one-fourth mile south of Empire Bridge, m lower dark clay beneath lower conglomerate, lower part of ebra formation, Oligocene; Station 6012*a*; Cat. No. 324296, .N.M.

LEPAS INJUDICATA, new species.

Plate 67, fig. 5.

This species is based upon a calcareous plate believed to be h
scutum of a Lepadid barnacle. It is thin, trapezoidal in outline, h
basal border straight, almost equal to the length, and a little n
tracted or narrowly bent in. The tergal extremity is broad a
somewhat convex. The occludent margin is almost straight. h
surface has the curvature of an ordinary *Lepas*, such as *L. anati* r
and is sculptured with coarse, unequal concentric folds, with c
wards the growing edges, some rather fine concentric striation.

The fossil is imperfect at the tergal end, but if restored accor n
to the lines of growth it would be about 25 mm. long; width 23 m

That the fossil has been correctly interpreted is by no means er
tain. If Lepadid, as believed, the very obtuse tergal end prob l
indicates a small, transversely placed tergum, not running bet e
scutum and carina, or perhaps none. Either condition would de o
greater specialization than the modern genus *Lepas*. However hi
may be, the fossil is specifically recognizable by its form and s lp
ture, and we must await the finding of further material to r ea
its nature.

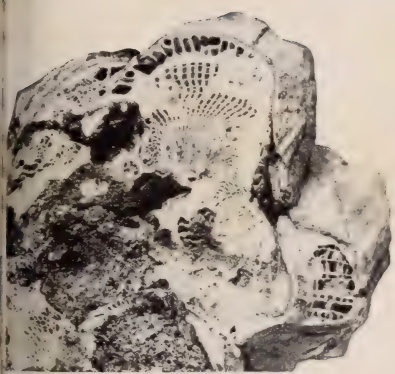
Locality and geologic occurrence.—The holotype is No. 32 4s
U.S.N.M. It was found by MacDonald and Vaughan in a secti o
the bluffs exposed along the Panama Railroad. Relocation, a ou
3,500 feet south of Gatun Railroad Station, in bed No. 6033*b*, C m
formation. Miocene series.

EXPLANATION OF PLATE 67.

FIG. 1. *Balanus glyptopoma* Pilsbry. Lateral view of group from Station 6
2. Rostral view of a specimen of *B. glyptopona* growing on *Pecten*, S ti
3. Basal view of fig. 1.
5903, the outer lamina of the wall removed. Length of r rum
16 mm.
4. *Balanus concavus rariseptatus* Pilsbry. Type.
5. *Lepas injudicata* Pilsbry. Type.

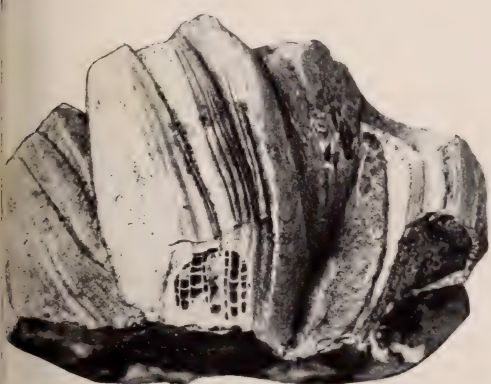
○

4



3

5



1

2

PANAMA CIRRIPEDES.

FOR EXPLANATION OF PLATE SEE PAGE 188.

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 103

ONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

FOSSIL CORALS FROM CENTRAL AMERICA, CUBA, AND PORTO RICO, WITH AN ACCOUNT OF THE AMERICAN TERTIARY, PLEISTOCENE, AND RECENT CORAL REEFS

By THOMAS WAYLAND VAUGHAN

Custodian of Madreporaria, United States National Museum, and Geologist in charge of Coastal Plain Investigations, United States Geological Survey

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FOSSIL CORALS FROM CENTRAL AMERICA, CUBA, AND PORTO RICO, WITH AN ACCOUNT OF THE AMERICAN TERTIARY, PLEISTOCENE, AND RECENT CORAL REEFS.

By Thomas Wayland Vaughan,

Custodian of Madreporaria, United States National Museum, and Geologist in charge of Coastal Plain Investigations, United States Geological Survey.

INTRODUCTION.

The object of the present memoir is to contribute information that may aid in deciphering the geologic history of the perimeters of the Gulf of Mexico and the Caribbean Sea. Therefore, problems of correlation, the physical conditions under which the different formations were deposited, and the distribution of land and sea during the successive geologic epochs have been particularly in mind.

The material on which this paper is based is extensive. It includes collections made in Panama by Dr. D. F. MacDonald and me, working jointly, and by Doctor MacDonald while alone; and Dr. Ralph Arnold obtained a small but valuable lot of specimens at Empire in the Canal Zone. The collections from Cuba were made by Dr. Arthur C. Spencer, Mr. O. E. Meinzer, and myself; the one from Porto Rico was made by Mr. R. T. Hill, who also obtained a small but valuable lot of specimens in Antigua; the principal collections from Antigua and Anguilla are the results of my individual efforts, and I obtained considerable material in St. Bartholomew, but not so much as Cleve got in 1869. There are numbers of small lots, as follows: One from Nicaragua, obtained by Dr. C. W. Hayes; one from Colombia, collected by Mr. G. C. Matson; specimens from Limon, Costa Rica, procured by Doctor Wailes and Mr. H. Pittier; and specimens from eastern Mexico, obtained by Mr. E. T. Dumble. All of the collections mentioned are the property of the United States National Museum, having been made in connection with official work of some kind, or the material, if privately collected, has been presented to the Museum. Messrs. Matson, Wailes, Pittier, and Dumble have presented specimens. My own collecting in Antigua, St. Bartholomew, and Anguilla was made possible by a minor grant from the Carnegie Institution of Washington, and as a result I brought some thousands of specimens to Washington.

These were presented to the United States National Museum by the Carnegie Institution.

Besides having studied the material indicated, I have twice been able to examine all of Duncan's types preserved in the Museum of the Geological Society of London and in the British Museum (Natural History), and I heartily thank the officers of those institutions for the privileges accorded me. In 1904 Prof. A. G. Högbom and Prof. C. Wiman most generously permitted the Cleve collection from St. Bartholomew and Anguilla to be sent to me in Washington. This collection contained all of Duncan's types from St. Bartholomew; and I thank Messrs. Högbom and Wiman for the excellent opportunity they gave me. Some duplicates from the Cleve collection, identified by direct comparison with Duncan's types, were procured for the United States National Museum by exchange.

Opportunities to study the Gabb collection from Santo Domingo, divided between the Philadelphia Academy of Natural Sciences and the Museum of Comparative Zoology, and the specimen obtained by Miss Carlotta J. Maury in Santo Domingo, have been very valuable. In fact, as a result of Miss Maury's careful stratigraphic studies in that Republic, the stratigraphic relations of the Santo Domingan faunas became known. Except retaining a few duplicates, she has generously presented to the United States National Museum the material obtained by her.

I wish to thank my associates in the United States National Museum and in the United States Geological Survey for their helpfulness during the prosecution of this study. Mr. W. O. Hazard, of the Survey photographic laboratory, made most of the photographs used for illustrations, and Miss Frances Wiesser retouched some of them.

There is almost no literature on the Tertiary fossil corals of Central America, Cuba, or Porto Rico. I listed a few Pleistocene species obtained by Mr. R. T. Hill at a place 1½ miles west of Port Limon, Costa Rica;[1] and Felix has recorded from Colombia[2] three species, as follows:

Orbicella theresiana Felix, probably a synonym of *Solenastrea bournoni* M. Edward and Haime.

Isastraea turbinata Duncan.

Stephanocoenia cf. *S. fairbanksi* Vaughan.

None of these records is further considered in the present paper.

Toula has described *Oculina gatunensis* from Gatun (see footnote, page 352 of this paper).

GEOLOGIC CORRELATION BY MEANS OF FOSSIL CORALS.

That vegetative variation in corals is great and that without large suites of specimens the limits of variation can not be ascertained

[1] Mus. Comp. Zool. Bull., vol. 28, p. 275, 1898.

[2] Felix, J., Ueber einige fossile Korallen aus Columbien, K. Bayer. Akad. Wiss., math.-phys. Sitzungsber., vol. 35, pp. 85–93, 1905.

wo facts so well known to students of Madreporaria that they need ly to be mentioned. I can not be sure that all of the supposed pecies recorded in this paper as valid are really valid; and perhaps identifying specimens from one locality with species from other calities I may not always have discriminated closely enough. I m discussing close resemblances and minute differences, for these e the basis of correlation within such regional limits as the borders the Gulf of Mexico and the Carribbean Sea, and the recognition nd proper evaluation of this kind of resemblances and differences ffect the reliability of the deductions as to age equivalence. I have een as careful as I well could be, but I should not like to insist that am always right in these very refined matters of observation and inferences based on such refined observation. In order to mini-ize error inherent in such work, I have tried not to rely on one pecies, but on groups of species—for instance the species of *Orbi-lla* and of *Goniopora* in both the Emperador limestone and the nguilla formation—and I have utilized the testimony of other roups of organisms.

Comparisons of faunas according to the percentages of species in ommon may be very misleading. Faunas now living only a short istance from each other may have nothing or almost nothing in ommon. In order to illustrate this I am introducing a table of the orals obtained in the Cocos-Keeling Islands by Dr. F. Wood Jones.[1] lthough the list has been published elsewhere, it is not very long nd strikingly illustrates faunal phenomena that are of great geologic nportance.

ist of corals obtained by Dr. Wood Jones in Cocos-Keeling Islands and their habitat.

br.=branching; frag.=fragile; msv.=massive; pl.=plate; incrust.=incrusting.

Name of species and growth-form.	Habitat.		
	Lagoon.	Barrier pools and barrier flat.	Exposed barrier.
riatopora angulata Klunzinger, delicately branched	×		
cillopora bulbosa Ehrenberg, br., form depends on environment	×		
damicornis (Esper), br., rather strong	×	×	
verrucosa (Ellis and Solander), stout br			
elegans Dana, strong br., aborted on surf	×		×
eydouxi M. Edwards and Haime, br., rather strong	×		
woodjonesi Vaughan, br., rather strong		×	
bicella versipora (Lamarck), msv			×
yphastrea microphthalma (Lamarck), msv		×	
hinopora lamellosa (Esper), thin folia	×		
ptastrea purpurea (Dana), msv		×	
bottae (M. Edwards and Haime), msv	×	×	
immersa Klunzinger, msv		×	
avia stelligera (Dana), msv	×	×	×
speciosa (Dana), msv. (dead specimen)			
avites abdita (Ellis and Solander), msv	×		
melicerum (Ehrenberg), msv. (dead specimen)			
ptoria phrygia (Ellis and Solander), msv	×		
ydnophora microconos (Lamarck), msv. (dead specimen)			
exesa (Pallas), lobate			

[1] Vaughan, T. W., Some shoal-water corals from Murray Island (Australia), Cocos-Keeling Islands, d Fanning Island, Carnegie Inst. Washington, Pub. 213, pp. 70-72, 1918.

List of corals obtained by Dr. Wood Jones in Cocos-Keeling Islands and their habi
Continued.

Name of species and growth-form.	Habitat.		
	Lagoon.	Barrier pools and barrier flat.	Ex ed bar r.
Fungia fungites (Linnaeus), free disk	×	×	
scutaria Lamarck, free disk		×	
Herpetolitha crassa Dana, free coral	×		
Pavona danai (M. Edwards and Haime), strong folia	×		
maldivensis (Gardiner), msv		Lagoon edge of barrier.	
varians Verrill, msv		×	
Psammocora haimiana M. Edwards and Haime, msv.		×	
sp., incrust	Sand flats.		
Dendrophyllia willeyi (Gardiner), msv			
diaphana Dana, incrust, base, protub. corallites			
Astreopora myriophthalma (Lamarck), msv		×	
Montipora levis Quelch, br	×		
tortuosa (Dana), frag., br	×		
ramosa Bernard, frag., br	×	Especially inner margin.	
cocosensis Vaughan, br		Lagoon side.	
spumosa (Lamarck), msv			
sp., lobate columns		Lagoon side.	
informis Bernard, msv., pl. on lower edges			
foliosa (Pallas), thin folia	×		
Acropora pulchra (Brook), frag., br	×		
pharaonis (M. Edwards and Haime), br	×	×	
forma *arabica* (M. Edwards and Haime)			
corymbosa (Lamarck), corymbose	Lagoon inlet.		
spicifera (Dana), corymbose		×	
scherzeriana (Brueggemann), msv. base, stout br.			
ocellata (Klunzinger), msv. lob			
variabilis (Klunzinger), br		×	
palifera (Lamarck), strong br	×		
Porites solida (Forskål), msv			
somaliensis Gravier, msv			
lichen Dana, incrust			
nigrescens Dana, br	×		
Millepora dichotoma Forskal, br		Inner margin of barrier.	
platyphylla Ehrenberg, strong folia			
sp., incrust			
Total number of species according to locality	23	20	16

Of the 23 species found in the lagoon, 3 also occur on the expo d barrier, and one of these is so modified to meet surf conditions t t ordinarily the specimens from the two localities would not be o- ognized as belonging to the same species. Thirteen per cent of e lagoon species occur on the exposed barrier; while 18 per cent f the exposed-barrier species occur in the lagoon. These are e relations within perhaps half a mile. There are 20 species in e barrier pools and on the barrier flat. Of these 6 occur within e lagoon and 2 were obtained on the exposed barrier; or there e 30 per cent in common with the lagoon and 10 per cent in comm n with the exposed barrier. When such relations as these pre il among the living corals of a small group of small islands, what e the chances that we should among fossil corals get a large percent e of common species?

The collection listed shows that certain species do occur in ll three habitats, and, by searching, spots may be found where e

inas of the different habitats mingle. Corals of the same habitat ould be compared, or groups of species of the same genera, as I ve done for Empire (Canal Zone) and Anguilla, where the habitats e nearly enough alike for the same genus to thrive in both. Unss it can be established that the habitats are ecologically very arly the same the percentages can not be used safely.

OLOGIC HISTORY OF THE UPPER EOCENE AND LATER CORAL AUNAS OF CENTRAL AMERICA, THE WEST INDIES, AND THE ASTERN UNITED STATES.

Eocene.

BRITO FORMATION, NICARAGUA.[1]

Dr. C. W. Hayes collected on or near the Pacific coast of Nicaragua e following species:

Astrocoenia d'achiardii Duncan.

Syzygophyllia hayesi Vaughan.

ST. BARTHOLOMEW LIMESTONE.[2]

I am introducing the name St. Bartholomew limestone for the per Eocene limestones of St. Bartholomew. Description of the ck, its stratigraphic relations, and summaries of its faunal charters are given in the papers referred to in the footnotes. Only o species of corals found in the St. Bartholomew limestone are tually described in the present memoir, namely:

Astrocoenia d'achiardii Duncan.

incrustans (Duncan) Vaughan.

The fossil corals from the St. Bartholomew limestone have been ecially considered by Duncan[3] and myself. Prof. A. G. Högbom, the University of Upsala, kindly lent me in 1904 the entire Cleve llection from St. Bartholomew, and in 1914 I spent eight days udying and collecting on the island. I am combining both the eve and my collections in the following list, and am adding e names of the Jamaican Eocene species, several of which also

---

[1] For an account of the Brito formation, see Hayes, C. W., Physiography and geology of region adjacent the Nicaragua Canal route, Geol. Soc. Amer. Bull., vol. 10, pp. 285–348, 1910. Description of the Brito nation, pp. 309–313.

[2] For accounts of the geology of St. Bartholomew, see as follows: Cleve, P. T., On the geology of the theastern West India Islands, K. svenska Vet.-Akad. Handl., vol. 9, No. 12, pp. 24–27, 1872. Vaughan, W., Study of the stratigraphic geology * * * of the smaller West Indian Islands, Carnegie Inst. shington Yearbook No. 13, pp. 358–360, 1915; also Yearbook No. 14, pp. 368–373, 1916; [Present status eologic correlation of the Tertiary and Cretaceous formations of the Antilles], Washington Acad. Sci. r., vol. 5, p. 489, 1915; Reef-coral fauna of Carrizo Creek, Imperial County, California, and its significe, U. S. Geol. Survey Prof. Pap. 98–T, pp. 362, 363, 1917.

Duncan, P. M., On the older Tertiary formations of the West-Indian Islands, Geol. Soc. London Quart. rn., vol. 29, pp. 548–565, pls. 19–22, 1873.

aughan, T. W., Some Cretaceous and Eocene corals from Jamaica, Mus. Comp. Zool. Bull., vol. 34, 227–250, 255–256, pls. 36–41, 1899; A critical review of the literature on the simple genera of the Madrearia Fungida, with a tentative classification, U. S. Nat. Mus. Proc., vol. 28, pp. 371–324, 1905; Study of stratigraphic geology * * * of the smaller West Indian Islands, Carnegie Inst. Washington Yearok No. 13, pp. 358–360, 1915; The reef-coral fauna of Carrizo Creek, Imperial County, California, etc., S. Geol. Survey Prof. Pap. 98–T. pp. 362–363, 1917.

occur in St. Bartholomew. Duncan described Eocene species fr m Jamaica in the papers referred to in the footnotes below.[1]

Eocene corals from St. Bartholomew and Jamaica.

Revised name.	St. Bartholomew.	Jamaica.			Notes.
		Catadupa formation.	Richmond formation.	Cambridge formation.	
Placotrochus clevei (Duncan)	×				*Turbinoseris clevei* Duncan.
Asterosmilia pourtalesi Duncan	×				
new species	×				*Flabellum appendiculatum* n can, *not* Brogniart.
Trochosmilia new species	×				
hilli Vaughan		×			
Stylophora compressa Duncan	×				
contorta (Leymerie) (fide Duncan)			×		
Astrocoenia duerdeni (Vaughan)	×		×		*Stylocoenia duerdeni* Vaugh
incrustans (Duncan)	×				*Stephanocoenia incrustans* n can.
d'achiardii Duncan	×				
Antillia (?) *compressa* (Duncan)	×				*Circophyllia compressa* Dun
(?) *clevei* (Duncan)	×				*Circophyllia clevei* Duncan.
species	×				
Columnastrea eyeri Duncan					"Eocene of Jamaica."
Favia new species 1	×				
new species 2	×				
Goniastrea variabilis Duncan	×				
Maeandra new species 1	×				*Manicina areolata* Duncan *not* Linnaeus.
new species 2	×				*Ulophyllia macrogyra* Du *not* Reuss.
Leptoria profunda Duncan	×				
conferticosta (Vaughan)		×			*Diploria conferticosta* Vaugh
conferticosta var. *columnaris* (Vaughan)		×			
Trochoseris catadupensis Vaughan		×			
Antilloseris eocaenica (Duncan)	×				
major (Duncan)	×				These three "species" m be reduced to one.
grandis (Duncan)	×				
jamaicaensis (Vaughan)	×			×	
cantabrigiensis (Vaughan)	×			×	
angulata (Duncan)	×				
cyclolites (Duncan)	×				
Physoseris insignis (Duncan)	×				*Trochosmilia insignis* Dun + *T. arguta* Duncan, *not* l ss.
Protethmos (?) new species 1	×				*Trochosmilia subcurvata* Du an, pl. 19, fig. 1, *not* Reuss.
new species 2	×				*Trochosmilia subcurvata* Du an, pl. 19, fig. 1*a*, *not* Reuss.
new species 3	×				
new species 4	×				
Metethmos (?) new species	×				
Dendracis cantabrigiensis Vaughan				×	
Actinacis new species	×				*Astraeopora panicea* Dunc Pictet.
Multicolumnastraea cyathiformis (Duncan)		×			
Goniopora new species 1	×				*Actinacis rollei* Duncan Reuss.
new species 2	×				*Porites ramosa* Duncan Catullo.

The following names in Duncan's list of St. Bartholomew c ls are dropped, because the specimens on which he based his de r- minations could not be found:

[1] Duncan, P. M., and Wall, G. P., A notice of the geology of Jamaica, especially with reference the district of Clarendon; with descriptions of the Cretaceous, Eocene, and Miocene corals of the island ol. Soc. London Quart. Journ., vol. 21, pp. 1–15, pls. 1, 2, 1865 (the descriptions of the corals are by Du n). Duncan, P. M., On the fossil corals (Madreporaria) of the West Indian Islands, Geol. Soc. London art. Journ., vol. 24, pp. 9–33, pls. 1–2, 1867.

Stylophora distans (Leymerie).
conferta Reuss.
tuberosa Reuss.
granulata Duncan.
Stephanocoenia elegans (Leymerie).
Astrocoenia multigranosa Reuss.
ramosa (Sowerby).
Plocophyllia caliculata (Catullo).
Solenastraea columnaris Reuss.

The revised list of the St. Bartholomew coral-fauna contains 33 species, two of which may be referred to the synonymy, but a few species may be added from the collection I made, the study of which is not quite complete. I have described and have had figures made of all the species in the Cleve collection. I hope soon to add descriptions of the specimens I obtained and then to publish a full account of the fauna.

I seriously doubt the Catadupa corals being Eocene; it seems more probable that they are Cretaceous. The species I described as *Trochosmilia hilli* is probably a fungid coral. The Richmond "beds" of Jamaica contain two species, one of which is found in the St. Bartholomew limestone. The Cambridge "beds" contain three species, two of which also occur in the St. Bartholomew limestone. The correlation of the Richmond and Cambridge formations of Jamaica with the St. Bartholomew limestone, seems to be well founded.

JACKSON FORMATION AND OCALA LIMESTONE.

The corals of the upper Eocene Jackson formation in the Gulf States are described in monograph cited below.[1] The species are as follows:

Flabellum cuneiforme var. *wailesi* Conrad.
Aldrichiella[2] *elegans* (Vaughan).
Turbinolia pharetra Lea.
Trochocyathus lunulitiformis (Conrad).
var. *montgomeriensis* Vaughan.
Caryophyllia dalli Vaughan.
Parasmilia ludoviciana Vaughan.
Archohelia burnsi (Vaughan).[3]
Astrangia expansa Vaughan.
ludoviciana Vaughan.
harrisi Vaughan.[4]
Platycoenia jacksonensis Vaughan.
Balanophyllia irrorata (Conrad).

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[1] Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States, U. S. Geol. Survey Mon. 39, pp. 263, 24 pls., 1900. See especially p. 30.
[2] Changed from *Aldrichia*.
[3] Changed from *Astrohelia*.
[4] Name added.

Endopachys maclurii (Lea).
var. *triangulare* Conrad.
shaleri Vaughan.[1]
minutum Vaughan.

A comparison of this list with the one of the St. Bartholomew and Jamaican corals reveals nothing in common; but I believe it can be made clear that the two faunas are of nearly the same age. That the Jackson formation in Mississippi and Louisiana is a shallow-water deposit is indicated by the nature of the sediments, the growth of specimens of *Astrangia* on rounded, somewhat indurated balls of sand, such as are common along some beaches, the presence of oyster shells, etc. The striking difference between the Jackson and St. Bartholomew coral faunas is due neither to great difference in geologic age nor to difference in the depth of water in which the faunas lived, but it is due to difference in the temperature of the water. The St. Bartholomew is a tropical fauna; the Jackson a temperate fauna.

The correlation of the St. Bartholomew limestone, the Richmond and Cambridge formations of Jamaica, and the Brito formation of Nicaragua with the Jackson formation of the Gulf States has been made possible by the work of C. W. Cooke and J. A. Cushman. Cooke shows in the paper cited in the footnote [2] that the Ocala limestone of southern Georgia and Florida is of Jackson age; and in more recent papers he [3] describes the stratigraphic occurrence, and J. A. Cushman [4] describes the species of the orbitoid genus of foraminifera *Orthophragmina* from the Ocala limestone in southern Georgia and Florida. The following is a list of the species:

Orthophragmina flintensis Cushman.
floridana Cushman.
americana Cushman, *st.*
mariannensis Cushman, *st.*
mariannensis var. *papillata* Cushman, *st.*
georgiana Cushman, *st.*
vaughani Cushman, *st.*

Those species whose names are followed by "*st.*" are stellately marked or are stellate in form. The Ocala limestone is a shoal-water deposit, laid down in a sea having a tropical temperature.[5] One of the results of my collecting in St. Bartholomew was to find in the St. Bartholomew limestone a stellate species of *Orthophragmina*,

[1] Name added.

[2] Cooke, C. W., The age of the Ocala limestone, U. S. Geol. Survey Prof. Pap. 95-I, pp. 107-117, 19

[3] Cooke, C. W., The stratigraphic position and faunal associates of the orbitoid foraminifers of the *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Pap. 108-G, pp. 109-113, 1917.

[4] Cushman, J. A., Orbitoid foraminifera of the genus *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Pap. 108-G, pp. 115-124, pls. 40-44.

[5] Vaughan, T. W., A contribution to the geologic history of the Floridian Plateau, Carnegie Inst. Washington Pub. 133, pp. 150-153, 1910.

arly related to *O. mariannensis* Cushman, and a second species of *Orthophragmina* that is of lenticular form. I also collected two species of *Nummulites* and one species of *Lepidocyclina* in St. Bartholomew. *Lepidocyclina* occurs in Georgia as far down stratigraphically as a horizon about the middle of the Jackson formation, and apparently as low as the base of the formation. The presence of species of *Orthophragmina* so similar to *O. mariannensis* seems to warrant the correlation of the St. Bartholomew limestone with the upper part of the Ocala limestone of Florida and Georgia, and therefore with the Jackson formation in Mississippi and in the States further westward.

Regarding the Brito formation of Nicaragua, it must be recognized that a single poor specimen of coral furnishes slim evidence on which to base a correlation. Doctor Cushman submits the following statement regarding the foraminifera from the Brito formation:

As to the Brito material, two lots especially are of interest. No. 6411 "coast about 2 m. s. e. of Brito Harbor" marked "Ool. fos. l. s." has abundant orbitoids with a beautifully ornamented exterior which without the confirmatory evidence of sections seem to be clearly *Orthophragmina* of a group not so far represented in the material studied. From No. 6408 two miles n. w. of Brito Harbor, however, there is more evidence. The material is very different and contains specimens which in accidental section show definite chambers of *Orthophragmina* of a different group. This does not however suggest either of the species from St. Bartholomew. Associated with it is a species of the flattened, broadly spiral form of nummulites. In the St. Bartholomew material there is such a form but of a species very much larger.

Now there is on the other hand a closer resemblance, that is to the lowest material of the Flint River collections. The Brito species of *Orthophragmina* is similar so far as I have made out to the one I have called *O. flintensis*. Moreover it is associated at Brito as along the Flint River with this broadly spiral, flattened form of nummulite. The specimens of nummulite from the two localities are very close in form and size and only differ in minute details. They may not be specifically identical in final analysis but are very close.

The statement by Doctor Cushman seems conclusive.

A horizon very nearly the same is recognizable in Colombia as the following quotation from Doctor Cushman shows:

Now, as to the specimen from one league west of Arroyo Hondo, Bolivar, Republic of Colombia. There is an association of *Nummulites* and stellate orbitoids which very decidedly suggests Eocene. While I can not definitely make out the equatorial chambers, the stellate form is very apparent in several specimens, and I should say specifically different from any of the species of *Orthophragmina* described in my paper from Georgia and Florida; in fact, they represent a very different group, I think, but are undoubtedly *Orthophragmina*.

Eocene deposits of the same or nearly same horizon as the St. Bartholomew limestone are widely distributed in Cuba, as is indicated by species of *Orthophragmina* and a number of echinoid species that also occur in St. Bartholomew.

CONCLUDING REMARKS ON THE EOCENE.

From the foregoing discussion it is clear that marine upper Eoce... formations are widely distributed in the southern United States, t... West Indies, Central America, and northern South America, a... that the Atlantic and Pacific Oceans were connected at that tir... One of the areas in which there was such a connection was acr... the present site of eastern Nicaragua.

Haug, I believe, correctly correlated the Jackson of Mississi... and other Gulf States with the Bartonian-Ludian (Priabonian) f... Europe.[1]

Attention should be directed to a statement by Oppenheim [2] ... which he suggests that the St. Bartholomew coral-fauna might ... the equivalent of the Priabona formation. The sequence I ... giving three of the important American horizons precisely par... lels Oppenheim's order, as expressed on page 13 of his work cit... It is as follows:

Oligocene:

Middle (Stampian = Rupelian = Antiguan).

Lower (Sannoisian = Lattorfian = Vicksburgian).

Eocene:

Upper (Priabonian = Ludian = Jacksonian = horizon of ... Bartholomew limestone, etc.).

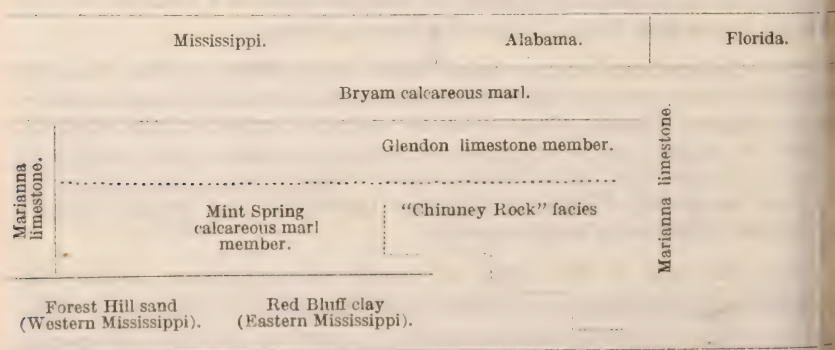
OLIGOCENE.

LOWER OLIGOCENE.

The lower Oligocene corals of the United States have been ... scribed by me.[3]

Dr. C. W. Cooke, in a paper recently published, subdivides ... Vicksburg group in Mississippi, Alabama, and Florida as follows:

Subdivisions of the Vicksburg group in Mississippi, Alabama, and Florida.



[1] Haug, Émile, Traité de géologie, vol. 2, p. 1523, 1911.

[2] Oppenheim, P., Die Priabonaschichten und ihre Fauna, Palaeontographica, vol. 47, pp. 348, 2... 1901.

[3] Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States, U. S. Geol. Su... Mon. 39, pp. 263, pls. 24, 1900. See especially p. 30.

The "coral limestone," formerly referred to the top of the Vicksburg group, as will be shown on subsequent pages, is, in my opinion, equivalent to the basal part of the Chattahoochee formation. The following is a list of the species of corals at present known from the Vicksburg group:

Fossil corals from the Vicksburg group.

Name.	Byram calcareous marl.	Marianna limestone.		Red Bluff clay.
		Glendon limestone member.	Mint Spring calcareous marl member	
Cycloseris bellum magnocostatum Vaughan				×
rhomboideum Vaughan				×
Rhabdophyllia binolia insignifica Vaughan	?		×	×
Siderastrea siphonotrochus pulcher Vaughan				×
Stephanophyllia hohelia neglecta (Vaughan)				×
vicksburgensis (Conrad)	×		×	×
mississippiensis (Conrad)	×			
harrisi (Vaughan)				×
aldrichi (Vaughan)				×
Antiguastrea cellulosa (Duncan)	×			
Trochocyathus dinophyllia elongata Vaughan				×
caulifera (Conrad)		×	×	
caulifera var. *multigranosa* Vaughan				×
Trochocyathus hydrophyllia new species	×			

This fauna is different from any now known in the West Indies or Central America. It lived under conditions closely similar to those under which the Jackson fauna of the same area lived. It is important to note that *Antiguastrea cellulosa*, a species very abundant in the middle and sparingly present in the upper Oligocene, occurs in the uppermost beds of the Vicksburg group. The Oligocene coral reef represented by the "coral limestone" at Salt Mountain, Alabama, and at Bainbridge, Georgia, overlies the Vicksburg group, which can with considerable assurance be correlated with the lower Oligocene (Lattorfian) of Veneto and elsewhere in Europe. The greatly-developed Oligocene coral reefs of Antigua are to be correlated with the reefs of Bainbridge. They are therefore stratigraphically higher than the Vicksburg group and are of middle Oligocene (Rupelian = Tampian) age.

MIDDLE OLIGOCENE.

ANTIGUA FORMATION.[1]

The following list of species is based on a revision of Duncan's work on the Antigua corals,[2] after a study of his types in the collec-

[1] Name proposed by J. W. Spencer in his paper entitled On the geological and physical development of Antigua, Geol. Soc. London Quart. Journ., vol. 57, pp. 496–498, 1901. See also, Brown, Amos P., Notes on the geology of the Island of Antigua, Acad. Nat. Sci. Phila. Proc. for 1913, pp. 584–616, pls. 18–20, 1914. Vaughan, T. W., papers referred to in footnote on page 193; and Memorandum on the geology and underwaters of Antigua, B. W. I., Imperial Dep't of Agriculture West India Bull., vol. 14, No. 4, 5 pp., 1915.

[2] Duncan, P. M., On the fossil corals of the West Indian Islands, Part 1, Geol. Soc. London Quart. Journ., v. 19, pp. 408–458, pls. 13–16, 1863; Part 4, Idem., vol. 24, pp. 9–33, pls. 1, 2, 1867.

tions of Geological Society of London and the British Museum (Natural History), and principally the collection made by myself which contains 60 species. It seems that I failed to find 7 of the species reported by Duncan; and apparently Mr. Robert T. Hill and Dr. J. W. Spencer each obtained one species that I did not collect. I feel a little doubtful about two or three of Duncan's types having really come from Antigua. Each species whose name is preceded by an asterisk * is considered in the systematic part of this paper.

Fossil corals from the Antigua formation.

Name.	Distribution outside Antigua.	Nomenclatorial notes.
**Stylophora ponderosa* Vaughan	Salt Mt., Ala	
new species 1		
new species 2		
Pocillopora tenuis Duncan		
new species		
Madrepora new species		
**Stylocoenia pumpellyi* (Vaughan)	Bainbridge, Ga	*Stylocoenia lobato-rotun* Duncan, *not* M. Edwards and Haime.
new species		
**Astrocoenia guantanamensis* Vaughan	Cuba, Panama	
**decaturensis* Vaughan	Cuba, Bainbridge, Ga	*Astrocoenia ornata* Dun *not* M. Edwards and Hai
**portoricensis* Vaughan	Porto Rico	
new species		
Asterosmilia exarata Duncan var	Santo Domingo	
Genus indet. new species		
Euphyllia new species		
Antillia new species		
Leptomussa new species		
Genus indet. new species		
Cladocora recrescens Lonsdale	Chattahoochee formation, upper part, Ga.	
**Orbicella antillarum* (Duncan)	Montserrat	*Heliastraea antillarum* Dun
**costata* (Duncan)	Porto Rico, Canal Zone, Anguilla	*Heliastraea costata* (Dun Duncan.
**insignis* (Duncan)	Arube	*Heliastraea insignis* Dunc
**intermedia* (Duncan)		*Heliastraea radiata* var. *media* (Duncan).
**Antiguastrea cellulosa* (Duncan)	Porto Rico, Cuba, Fla., Ga., Miss., Mex., Anguilla, Arube.	*Heliastraea cellulosa* (Dun Duncan + *Isastraea turb* Duncan.
**var. curvata* (Duncan)		
**var. silecensis* Vaughan	Ga., Fla., Mex	
Diplothecastraea monitor (Duncan) Duncan.		
**Favia macdonaldi* Vaughan	Panama	
**Favites polygonalis* (Duncan)	Bainbridge, Ga	
new species		
Lamellastraea smythi Duncan		
Genus indet. new species		
Goniastrea reussi (Duncan)		*Stephanocoenia reussi* Dun
**Maeandra antiguensis* Vaughan	Panama	*Coeloria denselephantis* Dun
dens-elephantis (Duncan)		
**Leptoria spenceri* Vaughan	Cuba	*Maeandrina* species Dunc
**Manicina willoughbiensis* Vaughan		*Coeloria labyrinthiformis* Duncan, *not* Linnaeus.
**Pironastraea antiguensis* Vaughan	Cuba	
Pavona new species		
Leptoseris new species 1		
new species 2		
Haloseris new species		
**Siderastrea conferta* (Duncan)	Porto Rico, Canal Zone, Anguilla.	*Isastraea conferta* Duncan
**Cyathomorpha hilli* Vaughan		
**browni* Vaughan		
**belli* Vaughan		
**splendens* Vaughan		
**antiguensis* (Duncan)	Porto Rico, Cuba, Mex	*Heliastraea antiguensis* (Duncan) Duncan + *As affinis* Duncan + *As antiguensis* Duncan.
**tenuis* (Duncan)	Porto Rico, Cuba	*Heliastraea tenuis* (Dun Duncan.

Fossil corals from the Antigua formation—Continued.

Name.	Distribution outside Antigua.	Nomenclatorial notes.
ploastrea crassolamellata (Duncan)...	Porto Rico, Cuba, Ga., Canal Zone.	*Heliastraea crassolamellata* (Duncan) Duncan + vars. *magnetica*, *pulchella*, and *nobilis*.
*var. *magnifica* (Duncan)....	Porto Rico, Cuba, Ga.....	
*var. *nugenti* (Duncan).....	.....	+ var. *minor* Duncan.
drophyllia new species.....	.....	
*ropora *panamensis* Vaughan	Canal Zone	
new species 1.....	.....	
**saludensis* Vaughan.....	Canal Zone.....	
new species 2.....	.....	
*treopora *antiguensis* Vaughan.....	Canal Zone.....	
*tinacis *alabamiensis* Vaughan.....	Salt Mt., Ala.; Bainbridge, Ga.	
new species 1.....	Bainbridge, Ga.....	
new species 2.....	.....	
iopora new species 1.....	.....	
new species 2.....	.....	
*regularis (Duncan).....	.....	*Alveopora daedalaea* var. *regularis* Duncan.
*var. *microscopica* (Duncan)..	.....	
new species 3.....	.....	
**clevei* Vaughan.....	Anguilla, Canal Zone.....	
**portoricensis* Vaughan.....	Porto Rico.....	
**cascadensis* Vaughan.....	Anguilla, Canal Zone.....	
new species 4.....	.....	
new species 5.....	.....	
*iopora (?) *tenuis* (Duncan).....	.....	*Stephanocoenia tenuis* (Duncan) + *Rhodaraea irregularis* Duncan.
opora new species 1.....	.....	
new species 2.....	.....	

Three of the species recorded by Duncan from Antigua, in my opinion, are incorrectly identified and their names are dropped from the list. They are as follows:

Favoidea junghuhni Reuss, according to Duncan.

Heliastraea barbadensis Duncan.

Solenastraea turonensis (Michelin), according to Duncan.

Another species, *Astraea megalaxona* Duncan, is based on unidentifiable material, and its name is also dropped. The total number of recorded species from Antigua, therefore, is 69, and 5 varieties are recognized. Of the 33 species indicated as new, descriptions of 8 have been written and descriptions of 26 remain to be written at the time of making out the preceding table.

The number of species, 69, recognized is interesting for comparison with the number recorded for areas in which living reefs occur. Von Marenzeller [1] records 71 species from the Red Sea in his report on the *Pola* expedition corals Bedot [2] records a total of 74 species and 5 varieties from Amboina—a number that should be reduced by about 4, because of the reference of some names to the synonymy of other species listed, leaving the number of valid species at about 70. In my paper on the shoal-water corals from Murray Island, Australia I list 63 species from Murray Island and its vicinity in water not exceeding 18 fathoms deep, and report 51 species from Cocos-

[1] Von Marenzeller, E., Riffkorallen, Exped. S. M. Schiff *Pola* in das Rote Meer, Zool. Ergeb. 26, K. K. Akad. Wiss. Wien, Mat.-Naturwiss Cl., vol. 80, pp. 28–97, pls. 1–29, 1906.

[2] Bedot, M., Madréporaries d' Amboine, Rev. suisse de Zool., vol. 15, pp. 143–292, pls. 5–50, 1907.

Keeling Islands.[1] It is known that at least a few more than 31 species occur in these islands. Outside the main coral-reef zone the number of species is smaller. For instance, there are only 43 supposedly valid species recorded from water between 0 and 25 fathoms deep in the Hawaiian Islands and Laysan.[2] It is not certain that 3 of the species included in the number 43 were obtained in the Hawaiian Islands. The usual number of species obtained in Florida or the West Indies, in water less than 25 fathoms deep, where conditions are favorable for coral growth is about 35. There were on the Antiguan reef as many species of corals as are at present usual for one island or a small group of islands in the Indo-Pacific, and about twice as many species as are usual on a living West Indian reef.

The reason for referring the Antigua reefs to a horizon above the lower (Lattorfian) Oligocene is given on page 199. The following list of middle (Rupelian) Oligocene genera is taken from Fabiani,[3] but it is considerably revised and needs further revision:

Middle Oligocene (Rupelian) genera of corals in Veneto.

**Stylophora.*	*Montlivaultia?*	**Hydnophora.*	*Dimorphastrea?*
**Stylocoenia.*	*Leptaxis.*	**Leptomussa.*	*Cyathomorpha.*
**Astrocoenia.*	*Astrangia.*	*Mycetophyllia.*	*Hydnophyllia.*
Trochosmilia.	*Holangia.*	**Trochoseris.*	*Astraeomorpha*
Coelosmilia.	*Gombertangia.*	*Cyathoseris.*	*Acropora.*
Epismilia?	**Orbicella.*	**Mesomorpha.*	*Dendracis.*
Phyllosmilia?	*Solenastrea.*	*Comoseris?*	**Astreopora.*
Parasmilia.	**Antiguastrea.*	*Mycetoseris.*	**Actinacis.*
**Euphyllia.*	*Aplophyllia?*	*Leptophyllia?*	**Goniopora.*
Dichocoenia.	*Rhabdophyllia.*	*Stephanosmilia.*	**Porites.*
Stylina?	*Calamophyllia*	*Thamnasteria?*	**Alveopora.*
Grumia.	**Goniastrea.*		

* Indicates that the genus is also found in the middle Oligocene of the West Indies or the southern United States.

The generic characters of a number of the corals listed by Fabiani can not be ascertained without a restudy of authentically identified specimens in the light of modern systematic technique, which require that besides having an adequate knowledge of the morphology of the coral skeleton, the investigation shall proceed from a critical study of the type-species of the genera to be recognized to a similar critical study of the species to be generically identified, and that due attention shall be paid to the rules of zoological nomenclature as expressed in the International Code. I will point out in passing that there are in the United States National Museum 10 specimens of the coral to which Reuss applied the name *Cyathophyllia annulata*. It would be too great a diversion to give in this place a discussion of the literature on this species. This is a fungid coral,

[1] Vaughan, T. W., Some shoal-water corals from Murray Island (Australia), Cocos-Keeling Island and Fanning Island, Carnegie Inst. Washington Pub. 213, see especially pp. 67–72, 1918.

[2] Vaughan, T. W., Recent Madreporaria of the Hawaiian Islands and Laysan, U. S. Nat. Mus. Bull. No. 59, pp. 32–34, 1907. [The list referred to has been slightly revised and the number reduced by 2 names.]

[3] Fabiani, R., Il paleogene del Veneto, R. Univ. Padova Inst. Geol. Mem., vol. 3, pp. 229–231. 19[illegible]

th a synapticulate and perforate wall at and just below the calicu- margin, the wall at lower levels usually, but not invariably, coming solid. In Fabiani's list this species, under the generic me *Stephanosmilia* (name proposed by Reuss in 1874, not *Stephanosmilia* De Fromentel, 1862), comes between *Parasmilia* and *ocophyllia* (a synonym of *Euphyllia*). I do not know what the stematic relations of *Leptaxis* Reuss are. Reuss based the genus d the type-species, *L. elliptica* Reuss, on a single specimen from nte Grumi and seems not to have obtained another from anywhere. Until additional specimens of *L. elliptica* have been critically idied, *Leptaxis* is not an identifiable genus. Although Duncan nsidered *Leptaxis* a subgenus of *Antillia*, I think that it may be e of the simple fungid genera. The species referred to 10 genera, nose names are followed by a question mark," ?," should all be tically restudied.

The names of the genera preceded by an asterisk, "*", in the egoing table are also found in the middle Oligocene of the West dies or the southeastern United States. The following genera ve closely related species:

ylophora	*Euphyllia*	*Leptomussa*	*Actinacis*
ylocoenia	*Orbicella*	*Cyathomorpha*	*Goniopora*
trocoenia	*Antiguastrea*	*Astreopora*	*Alveopora*

I am not at all sure that some of the American middle Oligocene d the European Rupelian species are not identical.

Dr. Joseph A. Cushman has described the following species of *pidocyclina* from the collection I made in Antigua (not yet published):

Lepidocyclina gigas Cushman
undulata Cushman
undosa Cushman
favosa Cushman

L. undulata seems to be the largest known species of *Lepicocyclina*, me specimens attaining a diameter of 100 mm.

The calcareous algae, echinoids, Mollusca, and Bryozoa, as well as te Foraminifera of the Antigua formation will be described in a forthming volume to be published by the Carnegie Institution of Washgton. The Antigua formation must, in my opinion, be the type the American middle Oligocene.

PEPINO FORMATION OF PORTO RICO.[1]

The corals here listed were almost all collected by Mr. R. T. Hill. have added the names of a few additional species collected by mbers of the New York Academy Porto Rico Survey.

[1] For accounts of the geologic relations of this formation, see Hill, R. T., Notes on the forest conditions orto Rico, U. S. Dept. Agriculture Div. of Forestry Bull. No. 25, pp. 14, 15, 1889. Vaughan, T. W., eferences in footnote on pp. 193, 205.

Fossil corals from the Pepino formation.

Astrocoenia portoricensis Vaughan, Antigua, and Canal Zone.
Orbicella costata (Duncan), Antigua, Anguilla, Canal Zone.
Antiguastrea cellulosa (Duncan), Antigua, Florida, Georgia., etc.
Maeandra portoricensis Vaughan.
Leptoseris portoricensis Vaughan.
Pironastraea anguillensis Vaughan, Anguilla.
Siderastrea conferta (Duncan), Antigua, Canal Zone, Anguilla.
Cyathomorpha antiguensis (Duncan), Antigua, Cuba, Mexico.
tenuis (Duncan), Antigua, Cuba.
Diploastrea crassolamellata (Duncan), Antigua, Cuba, Georgia.
Astreopora portoricensis Vaughan.
Goniopora portoricensis Vaughan, Antigua.

Of the 12 species from the Pepino formation, 8 are known in t
Antigua formation of Antigua.

LIMESTONE ABOVE CONGLOMERATE NEAR GUANTÁNAMO, CUBA.

The geologic relations of the corals from the vicinity of Guan-
namo will be described by Mr. O. E. Meinzer in a forthcoming repo
The following is a list of the species:

Fossil corals from the middle Oligocene, Guantanamo, Cuba.

Pocillopora guantanamensis Vaughan.
Astrocoenia guantanamensis Vaughan, Antigua, Panama.
decaturensis Vaughan, Antigua, Georgia.
meinzeri Vaughan.
Antiguastrea cellulosa (Duncan), Antigua, Porto Rico, etc.
Trochoseris meinzeri Vaughan, Panama.
Pironastraea antiguensis Vaughan, Antigua.
Cyathomorpha anguillensis Vaughan, Anguilla.
antiguensis (Duncan), Antigua, Porto Rico, etc.
tenuis (Duncan), Antigua, Porto Rico, etc.
Diploastrea crassolamellata (Duncan), Antigua, etc.
Goniopora decaturensis Vaughan, Georgia.

Of the 12 species here listed 7 are also found in Antigua; of th
remaining species 2 are at present known from only one locality
occur elsewhere in association with a fauna of the same facies
that of Antigua, while 1 occurs in the base of the Anguilla formati

Limestone, Rio Canapu, Manasasas trail, Cuba.

The following species were collected by Dr. Arthur C. Spencer:
Leptoria spenceri Vaughan, Antigua.
Cyathomorpha tenuis (Duncan), Antigua.
Diploastrea crassolamellata (Duncan) Antigua.

The first and second species of the above list were obtained at s
tion No. 3473 of the U. S. N. M. record of localities for Cenozoic

ertebrate collections. Specimens of *Orthophragmina* were obtained the same station and indicate upper Eocene or lower Oligocene as ie age of the rock. This matter will be further discussed in the rthcoming report on West Indian paleontology.

BASAL PART OF CHATTAHOOCHEE FORMATION IN GEORGIA.[1]

The localities at which the specimens of fossil corals were obtained e at Blue or Russell Springs on Flint River about 4 miles below ainbridge, and at other localities along Flint River to Hale's Land- g, about 7 miles below Bainbridge. The corals are most embedded or weathered out of chert which was once a coral-reef limestone iat was formed on the subaerially eroded surface of the Eocene cala limestone after submergence. Dr. W. H. Dall in a recently iblished paper [2] appears to correlate this bed with the *Orthaulax ugnax* zone of Tampa, Florida, and states that I concur in that inion. Although the chert forming the base of the Chattahoochee rmation in the vicinity of Bainbridge is faunally nearly related to ie "silex" bed of the Tampa formation, in my opinion they are not the same age, the "silex" bed being geologically younger. The ral faunas are not the same, and there is at least a species of one mus at Tampa of stratigraphically later affinities than any species the vicinity of Bainbridge.

The following are the species from near Bainbridge mentioned in is paper:

Fossil corals from basal part of Chattahoochee formation near Bainbridge, Georgia.

Stylophora minutissima Vaughan.
Stylocoenia pumpellyi (Vaughan) Vaughan, Antigua.
Astrocoenia decaturensis Vaughan, Antigua, Cuba.
Orbicella bainbridgensis Vaughan, Santo Domingo?, Porto Rico.
Antiguastrea cellulosa (Duncan), Antigua, etc., Tampa.
var. *silecensis* Vaughan, Antigua, etc.
Favites polygonalis (Duncan) var., Antigua.
Siderastrea silecensis Vaughan, Tampa; Alum Bluff formation.
Diploastrea crassolamellata (Duncan), Antigua, etc.
var. *magnifica* (Duncan), Antigua, etc.
Astreopora antiguensis Vaughan, Antigua.
Actinacis alabamiensis (Vaughan), Antigua; Salt Mountain, Ala.
Goniopora decaturensis Vaughan, Cuba.

The more important references to the literature are as follows:
Vaughan, T. W., A Tertiary coral reef near Bainbridge, Georgia, Science, n. s., vol. 12, pp. 873-875, 1900; inbridge and vicinity in Preliminary report on the Coastal Plain of Georgia by O. Veatch and L. W. phenson, prepared under the direction of T. W. Vaughan, Geol. Survey of Ga. Bull. 26, pp. 328-333, 1; The reef coral fauna of Carrizo Creek, Imperial County, California, and its significance, U. S. Geol. rvey Prof. Pap. 98-T, pp. 363-364, 1917.
Cooke, C. W., Age of the Ocala limestone, U. S. Geol. Survey Prof. Pap. 95-I, pp. 107-117, 1915.
A contribution to the invertebrate fauna of the Oligocene beds of Flint River, Georgia, Proc. U. S. Nat. ., vol. 51, pp. 487-524, plates 83-88, 1916.

Of the 13 species and varieties listed above, 9 are common
Antigua, and *Goniopora decaturensis* occurs in Cuba in associati
with species of corals abundant in Antigua; of the 3 remaini
species, *Stylophora minutissima* has so far been positively identifi
only at Bainbridge, but it is very near a species common in Antigu
2 of the 13 forms are known from the "silex" bed of Tampa. T
coral fauna near Bainbridge is a moderately rich one. In additi
to those listed there are species of *Stylophora*, *Astrocoenia*, *Antillia*
Astrangia or *Rhizangia*, *Mesomorpha*, *Astreopora*, *Actinacis*, *Gon*
pora, and *Alveopora*, and of a few genera not yet positively identifie
There are between 25 and 30 species, of which only 4 or 5 are co
mon to the Tampa coral fauna.

It should be stated here that casts of a species of *Pecten*, whi
appears to *P. suwaneensis* Dall, occur at station 3381 in the mat
with *Diploastrea crassolamellata*, which may therefore be of upp
Eocene as well as of Oligocene age, or I may not have discriminat
closely enough between species.

"CORAL LIMESTONE" OF SALT MOUNTAIN, ALABAMA.[1]

I described in the monograph referred to in the footnote t
species, as follows:

Stylophora ponderosa Vaughan, Antigua.

Actinacis alabamiensis (Vaughan), Antigua; Flint River, Georgia

I long surmised that the "coral limestone" of Salt Mounta
really represented the basal part of the Chattahoochee formatio
but only recently did I obtain evidence that this limestone is t
stratigraphic correlative of the Antigua formation and of the co
reef horizon near Bainbridge.

SAN RAFAEL FORMATION OF EASTERN MEXICO.[2]

The formation from which the fossil corals were obtained w
first designated by Mr. Dumble "San Fernando beds," a name lo
in use for a Tertiary formation in the Island of Trinidad. He h
recently changed the name to San Rafael. It is an important form
tion in eastern Tamaulipas, Mexico. Several of the corals are r
well enough preserved for purposes of identification. The followi
is a list:

Antiguastrea cellulosa (Duncan), Antigua, etc.

var. *silecensis* Vaughan, Antigua, etc.

Favites mexicana Vaughan.

Maeandra dumblei Vaughan.

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[1] For a description of the geologic relations, see Vaughan, T. W., Eocene and lower Oligocene c
faunas of the United States, U. S. Geological Survey Mon. 39, pp. 30, 31, 1900.

[2] The principal literature is as follows:

Dumble, E. T., Some events in the Eocene history of the present Coastal area of the Gulf of Mexic
Texas and Mexico, Journ. Geol., vol. 23, pp. 481–498, 1915 (see especially pp. 495–497); Tertiary dep
of northeastern Mexico, California Acad. Sci. Proc., ser. 4, vol. 5, pp. 163–193, pls. 16–19, 1915 (see e
cially pp. 189–192).

Cyathormorpha antiguensis (Duncan), Antigua, etc.
Goniopora species. Similar to Antiguan species.
Although the identifiable species are few, it appears safe to correlate the San Rafael formation with the Antigua formation.

TONOSI, PANAMA.

Doctor MacDonald obtained at this locality, station 6587, the following species of corals:
Astrocoenia guantanamensis Vaughan, Antigua, Cuba.
Favia macdonaldi Vaughan, Antigua.
Maeandra antiguensis Vaughan, Antigua.
Trochoseris meinzeri Vaughan, Cuba.
Diploastrea crassolamellata (Duncan), Antigua, Cuba, etc.
There can be no reasonable doubt that this is the same as the coral fauna found in the Antigua formation. As the locality at which these specimens were obtained is on the Pacific coast of Panama, the evidence is conclusive that there was middle Oligocene connection between the Atlantic and the Pacific in that area.

SERRO COLORADO, ARUBE.

Three species were obtained at this locality,[1] as follows:
Orbicella insignis (Duncan), Antigua.
Antiguastrea cellulosa (Duncan), Antigua.
Goniopora species (the kind of casts to which Duncan applied the name *Alvepora daedalea* var. *regularis*).
This fauna is evidently the same as that of the Antigua formation.

CONCLUDING REMARKS ON THE MIDDLE OLIGOCENE.

The foregoing lists show that Antiguan middle Oligocene coral fauna is known in Porto Rico, Cuba, southern Georgia, southern Alabama, eastern Mexico, Panama, and Arube. That it also occurs in Santo Domingo is known from some of the specimens, *Siderastrea conferta* (Duncan) typical and a peculiar variety of *Asterosmilia marata* (Duncan), both brought from Santo Domingo by Gabb. It is a key horizon in the American Oligocene. The Byram calcareous marl of Mississippi occurs either at its base or just below its base. It therefore overlies all the Vicksburgian lower Oligocene, with the possible exception of the uppermost member, and is stratigraphically just below the "silex bed" of the Tampa formation. The correlation of the deposits containing this fauna with the Rupelian of Veneto has been made on page 202.
That there was middle Oligocene connection between the Atlantic and the Pacific was pointed out on this page in discussing the species from Tonosi, Panama.

[1] Vaughan, T. W., Some fossil corals from the elevated reefs of Curaçao, Arube, and Bonaire, Geolog. Reichs-Mus. Leiden Samml., ser. 2, vol. pp. 1–91, 1901 (especially pp. 11, 12).

UPPER OLIGOCENE.

CULEBRA FORMATION.

The Culebra formation and the base of the Emperador limestor in the Canal Zone contain a few species that indicate close relatio ship with the Antiguan horizon, but on the whole the affinities a rather with the next higher fauna. Fossil corals were obtained the Culebra formation at three stations, as follows:

Station 5863, west side of Gaillard Cut, at station 1863 of t Canal Commission, between points opposite Curacha and Paraiso.

Station 6020*c*, Las Cascadas, Gaillard Cut, third bed from t bottom of the section.

Station 6026, one and one-half miles south of Monte Lirio, Panama Railroad (relocated line).

The list of species is as follows:

Species of corals from the Culebra formation.

Name.	Station 5863.	Station 6020c.	Station 6026.	Empera-dor Is.	Antigua.	Anguil
Stylophora imperatoris Vaughan	×		×	×		×
goethalsi Vaughan			×	×		
Orbicella costata (Duncan)		×			×	×
Siderastrea conferta (Duncan)		×			×	×
Astreopora antiguensis Vaughan			×		×	
Goniopora cascadensis Vaughan		×			×	×

Of the 6 species in the Culebra formation, 2 also occur in t Emperador limestone; 4 also occur in the Antigua formation; and also occur in the Anguilla formation. There is only one speci *Astreopora antiguensis*, that is elsewhere known only from t Antigua horizon; while 2 species are at present known elsewhe only from the Anguilla horizon. These relations indicate, but do n prove, that the upper part of the Culebra formation, the part of t formation in which the corals were collected, is stratigraphical higher than the Antigua formation, and is, therefore, referable to t upper Oligocene. The foraminiferal fauna, to be discussed on pag 554, 555, 585, supplies stronger evidence in favor of considering t upper part of the Culebra as of upper Oligocene age.

EMPERADOR LIMESTONE.

The principal collections from the Emperador limestone were ma by Doctor MacDonald and me at Station 6015 and 6016, in Empi village. Dr. Ralph Arnold subsequently made a small collection Empire and obtained one species, *Pocillopora arnoldi* Vaughan, n collected by Doctor MacDonald and me. Doctor MacDonald a I also made a small collection at Station 6024*b*, the upper bed the lower end of the culvert where the Panama Railroad (relocat line) crosses Rio Agua Salud; and he subsequently obtained son

ery interesting specimens at station 6256, which is 1½ miles south f Miraflores. The following is a list of the species:

Species of corals from the Emperador limestone.

	Empire quarries.	Station 6024*b*.	Station 6256.	Anguilla.	Antigua.
ylophora imperatoris Vaughan	×	×		×	
panamensis Vaughan	×				
goethalsi Vaughan	×				
macdonaldi Vaughan	×	×			
canalis Vaughan	×				
cillopora arnoldi Vaughan	×				
trocoenia portoricensis Vaughan		×			×
bicella imperatoris Vaughan	×		×	×	
canalis Vaughan	×			×	
ylangia panamensis Vaughan	×				
niastrea canalis Vaughan	×				
wona panamensis Vaughan	×				
ropora panamensis Vaughan		×			×
saludensis Vaughan	×	×			×
treopora goethalsi Vaughan	×				
niopora hilli Vaughan	×				
panamensis Vaughan	×			×	
imperatoris Vaughan	×			×	
canalis Vaughan	×			×	
clevei Vaughan	×			×	×
rites douvillei Vaughan	×				
toulai Vaughan	×				
panamensis Vaughan	×		×		
anguillensis Vaughan	×			×	×
(*Synaraea*) *howei* Vaughan	×				
macdonaldi Vaughan	×			×	×

Of 26 species from the Emperador limestone, 6 have been identified the Antigua formation and 9 in the Anguilla formation, but it probable that the number of species common to the Emperador mestone and the Anguilla formation will be somewhat increased. he Emperador limestone is of nearly the same horizon as the Anuilla formation. Additional evidence favoring this opinion will be dduced on subsequent pages.

ANGUILLA FORMATION.[1]

This name is proposed for the coralliferous limestone and argillaeous marls of Anguilla. The type-locality is on the south and west des of Crocus Bay, where it is exposed to a thickness of about 200 et. The fauna has been monographically described, and the account f it will be published in a forthcoming volume of the Carnegie Institution of Washington. The following species of corals from it are onsidered in the present paper:

[1] The principal literature is as follows:
Cleve, P. T., On the geology of the northeastern West India Islands, K. svenska Vet.-Akad. Handl., l. 9, No. 12, p. 22, 1872.
Vaughan, T. W., see references in footnote, p. 193.

Species of corals from the Anguilla formation.

Name.	Cu'ebra formation.	Emperador limestone.	Antigua.	Other localities.
Stylophora imperatoris Vaughan	×	×		
Orbicella imperatoris Vaughan		×		Cuba.
costata (Duncan)	×		×	
canalis Vaughan		×		
Antiguastrea cellulosa (Duncan)			×	P. R.; Cuba; etc
Agaricia anguillensis Vaughan				
Pironastraea anguillensis Vaughan				P. R.
Siderastrea conferta (Duncan)	×		×	P. R.
Cyathomorpha anguillensis Vaughan				
roxboroughi Vaughan				
Goniopora panamensis Vaughan		×		
imperatoris Vaughan		×		
canalis Vaughan		×		
clevei Vaughan		×		
cascadensis Vaughan	×			
Porites anguillensis Vaughan		×		
(*Synaraea*) *macdonaldi* Vaughan		×		

P. R.=Porto Rico.

Of the 17 species listed above, 4 are also found in the Culebr formation, 9 in the Emperador limestone, and 12 of the 17 in th combined Culebra and Emperador of the Canal Zone. In additio to the species here considered there are other species of *Stylophor Stylocoenia*, *Antillia*, *Cladocora*, *Maeandra*, *Goniopora*, and *Porite* There are 9 or 10 species of *Goniopora*. The total coral fauna in th collections available to me comprises about 28 species.

The Anguilla formation is correlated with the Emperador limeston for the following reasons: *Heterosteginoides*, a new genus of orbitoid foraminifera described by Doctor Cushman, is represented in th Anguilla formation by a species, also found in Antigua, but ver near a species that occurs in the Emperador limestone. Althoug *Heterosteginoides* occurs in both Antigua and Anguilla, *Lepidocyclin* which is so abundant in Antigua, was not collected by me in Anguill and is only sparingly present in the Emperador limestone. Th identity of certain species of corals in the two formations has bee shown. *Echinolampas semiorbis* Guppy is abundant in Anguilla (o the west side of Crocus Bay between 25 and 70 feet above sea leve and in the base of the Emperador limestone, Canal Zone. *Orthaul pugnax* (Heilprin) was collected in the base of the Crocus Bay e posures.

CUBAN LOCALITIES.

Orbicella imperatoris Vaughan has been collected at the followin localities in Cuba: Station 3450, 4 miles north of Pinar del Ri station 3451, one-half mile west of Ciénaga railroad station, ne Habana; station 3566, Bejucal; station 7544, Rio Yateras, nea Guantanamo. That the Anguilla horizon is widely extended i Cuba is shown by the distribution of the echinoids which will b considered in another place.

TAMPA FORMATION OF FLORIDA.

The corals from the "silex" bed of the Tampa formation considered
n this paper are as follows:

Orbicella tampäensis Vaughan.
var. *silecensis* Vaughan.
Antiguastrea cellulosa (Duncan).
Siderastrea silecensis Vaughan.
Siderastrea hillsboroensis Vaughan occurs at about the same horizon
s the "silex" bed.

The Tampa coral fauna has not been described in print, but I
rnished Doctor Dall a list of my manuscript names of the species
nd it appeared in his monograph of the molluscan fauna of the
rthaulax pugnax zone of the Oligocene of Tampa, Florida.[1] I have
ointed out that *Orbicella tampaensis* var. *silecensis* (see p. 391 of this
aper) closely resembles some of the variants of *O. costata* from An-
uilla and that the specimens identified as *Siderastrea silecensis* in
hich there are over 60 septa perhaps should be referred to *S. con-
rta* (see p. 449). Besides the species mentioned, there are species
epresenting the following genera: *Stylophora, Antillia?, Galaxea,
olenastrea, Maeandra, Syzygophyllia?, Endopachys, Acropora, Gonio-
ora, Porites, and Alveopora.*

Two and perhaps three of the "silex" bed species of corals also
ccur at Bainbridge, but the faunas otherwise are not the same.
wo of the species from Tampa are near living West Indian and
loridian species. These are *Solenastrea tampäensis* Vaughan, *nomen
udum*, which is near *S. hyades* (Dana); and *Porites willcoxi* Vaughan,
omen nudum, which has the septal arrangement of *Porites astreoides.*
he presence of such species with modern affinities seems to me to indi-
ate a considerably younger age than that of the reefs near Bain-
ridge. Furthermore *Lepidocyclina* is abundant in the reefs near
ainbridge, but has not yet been found at Tampa. *Orthaulax pugnax*
ccurs in the "silex" bed at Tampa, but it has not been found in the
verlying limestone; the same species occurs in the base of the An-
uilla formation, but I did not find it at higher levels. Dr. C. W.
ooke, who has monographically described the mollusca of the
nguilla formation, correlates it with the Tampa formation on the
asis of similarity in their molluscan faunas. The correlation of the
ampa formation is further discussed on pages 570, 571.

CONCLUDING REMARKS ON THE UPPER OLIGOCENE.

That there was connection between the Atlantic and Pacific oceans
uring upper Oligocene time is shown by the continuity of both the
ulebra formation and the Emperador limestone from the Atlantic
) the Pacific slopes of the Isthmus. On the geologic map, plate 153,

[1] U. S. Nat. Mus. Bull. 90, p. 18, 1915.

the Emperador limestone is represented as dipping below the Gatu formation on the north side of the Isthmus, and it is exposed almo down to the sea level on the south side. The Culebra formatic underlies the Emperador limestone on both slopes, but it is not ind cated on the map on the north slope of the Isthmus.

Miocene.

BOWDEN MARL.[1]

The point of departure in the consideration of the Miocene is t fauna of the Bowden marl of Jamaica. The following is a revis list of the species:

Placotrochus costatus Duncan.
Sphenotrochus new species.
Placocyathus barretti Duncan.
alveolus (Duncan.)
Stylophora granulata Duncan.
Asterosmilia profunda (Duncan).
hilli Vaughan.
Stephanocoenia intersepta (Esper), also living.
Antillia walli Duncan.
Thysanus excentricus Duncan.
elegans Duncan.
new species.
Syzygophyllia gregorii (Vaughan).
Siderastrea siderea (Ellis and Solander), also living.
Goniopora new species.
Porites baracoäensis Vaughan.
Acropora new species.

This fauna indicates somewhat deeper water than that in whi the species mentioned on preceding pages lived; but the presence *Stephanocoenia intersepta*, *Siderastrea siderea*, *Acropora* new speci a massive species of *Goniopora*, and *Porites baracoäensis*, furnish ev dence in favor of the conclusion that the depth probably was not much as 20 fathoms. The most striking feature of this list is that contains the names of two species still living in the Caribbean regio in this respect differing from all the other faunas previously consi ered in this paper. The Bowden not only marks the introduction species that persist in the West Indian region, but as neither Jamaica, Santo Domingo, nor Cuba, have species of *Astrocoeni Stylocoenia*, *Leptomussa*, *Antiguastrea*, *Favites*, *Leptoria*, *Trochoser Leptoseris*, *Haloseris*, *Pironastraea*, *Mesomorpha*, *Cyathomorph Diploastrea*, *Astreopora*, *Actinacis*, or *Porites* (*Synaraea*) been fou in beds of the same age as or younger than the Bowden, the

[1] For an account of the stratigraphic relations of the Bowden marl, see Hill, R. T., The geology physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, No. 1, pp. 226, with 35 plates, (especially pp. 82–86, 145–152).

genera and one subgenus of middle and upper Oligocene corals parently had become extinct in this region. The genus *Thysanus* is esent in the Pliocene Caloosahatchee marl of Florida; and in Santo omingo *Placocyathus*, *Stylophora*, *Antillia*, and *Syzygophyllia* occur horizons above that of the Bowden marl, while the number of species w living increases. The Bowden marl marks an important change the character of the coral faunas, a change from an older to a more cent facies. It therefore seems to me that the Bowden marl can t be considered of Oligocene age, and that it must be referred to e lower Miocene.

SANTO DOMINGO.

With regard to the species reported by Duncan from Santo Doingo, it will be said that Duncan does not describe the stratigraphy Santo Domingo, but refers the specimens to the Nivajè shale, the perficial or tufaceous limestone, Posterero shale, Cerro Gordo ales, Esperanza shale, and "the silt of the sandstone plain." The llowing is a list of the species recorded by him, the geologic formaon in which they were reported to be found, and the revised names th annotations:

Fossil corals reported by Duncan from Santo Domingo.

Name used by Duncan.	Nivajè shale.	Superf. and tufaceous limestone.	Postrero shale.	Esperanza shale.	Silt of the sandstone plain.	Revised names and annotations.
bellum exaratum Duncan	.....	.....	.....	.....	.....	Described from Vere, Jamaica; genus doubtful; identification doubtful.
bellum new species	(?)	.....	.....	.....	.....	Not determinable.
cotrochus lonsdalei Duncan	+	.....	.....	.....	.....	*Placotrochus lonsdalei* Duncan.
atotrochus duodecim-costatus M. Edards and Haime.	.....	.....	.....	.....	.....	From yellow shale of Angostina, Santo Domingo; specimen not determinable.
chocyathus latero-spinosus M. Edwards ad Haime.	+	.....	.....	.....	.....	*Placocyathus* new species.
racyathus henekeni (Duncan) Duncan.	+	.....	.....	.....	.....	*Paracyathus henekeni* (Duncan).
cocyathus barretti Duncan	.....	.....	+	.....	.....	*Placocyathus barretti* Duncan; originally described from Bowden, Jamaica.
variabilis Duncan	+	.....	.....	.....	+	*Placocyathus variabilis* Duncan.
costatus Duncan	+	.....	.....	.....	.....	*Placocyathus costatus* Duncan.
illopora crassoramosa Duncan	+	.....	.....	.....	.....	*Pocillopora crassoramosa* Duncan.
lophoro affinis Duncan	+	.....	.....	.....	.....	*Stylophora affinis* Duncan.
var. *minor* Duncan	+	.....	.....	.....	.....	*Stylophora minor* Duncan.
lophora affinis Duncan var. 2	+	.....	.....	.....	.....	*Stylophora* new species; also from Cerro Gordo shales.
raristella M. Edwards and Haime.	.....	.....	.....	.....	+	Name discarded for Santo Domingan species.
chocyathus abnormalis Duncan	+	.....	.....	.....	.....	*Asterosmilia abnormalis* (Duncan).
crosmilia anomala Duncan	+	.....	.....	.....	.....	
cornuta Duncan	+	.....	.....	.....	.....	
exarata Duncan	.....	.....	.....	.....	.....	*Asterosmilia exarata* Duncan; also in Antigua formation, Antigua.
phanocoenia intersepta M. Edwards ad Haime.	.....	.....	.....	.....	+	*Stephanocoenia intersepta* (Esper).
illastraea spongiformis (Duncan) uncan.	.....	.....	.....	.....	+	
hocoenia tuberosa Duncan	+	+	.....	.....	.....	*Dichocoenia tuberosa* Duncan.
ysmilia intermedia Duncan	.....	.....	.....	+	.....	

Fossil corals reported by Duncan from Santo Domingo—Continued.

Name used by Duncan.	Nivajè shale.	Superf. and tufaceous limestone.	Postrero shale.	Esperanza shale.	Silt of the sandstone plain.	Revised names and annotations.
Flabellum dubium Duncan	+					*Antillia dubia* (Duncan).
Antillia lonsdaleia Duncan	+					
bilobata Duncan	+					*Antillia bilobata* Duncan.
Cyphastraea costata Duncan	+					The type of this is from B buda and is a precise sy nym of *Orbicella annul* (Ellis and Solander); but Santo Domingan specir is a species of *Solenastrea.*
Phyllocoenia sculpta M. Edwards and Haime var. *tegula* Duncan.	+					*Orbicella limbata* (Duncan); reported from "yellow sha
Phyllocoenia limbata Duncan						
Plesiastraea ramea Duncan					+	
Heliastraea cylindrica (Duncan) Duncan		+				Varietal forms of *Orbicella ernosa* (Linnaeus).
endothecata (Duncan) Duncan	+					
brevis (Duncan) Duncan	+					*Orbicella brevis* (Duncan).
Plesiastraea distans Duncan					+	Varietal forms of *Solenas bournoni* M. Edwards Haime.
globosa Duncan					+	
Solenastraea verhelsti M. Edwards and Haime.		+				A highly fossilized specir name discarded for the Sa Domingan coral.
Stephanocoenia dendroidea M. Edwards and Haime.						Locality not given; probab species of *Astrocoenia.*
Thysanus corbicula Duncan	+					*Thysanus corbicula* Duncan
Teleiophyllia grandis Duncan	+					*Thysanus grandis* (Duncan)
navicula Duncan	+					*Thysanus navicula* (Duncar
Manicina areolata (Linnaeus)	+					*Maeandra areolata* (Linnae
Maeandrina filograna Lamarck						"Shale," no other data on logic relations; name drop from list.
sinuosissima M. Edwards and Haime.					+	The name proposed by M Edwards and Haime i synonym of *Maeandra gosa* (Dana); name drop from list.
Lithophyllia affinis (Duncan) Duncan		+				*Mussa affinis* (Duncan); ma the young of *Mussa angu* (Pallas).
Antillia ponderosa (M. Edwards and Haime) Duncan.	+					*Syzygophyllia gregorii* (Vaugh type from Bowden, Jama
dentata Duncan	+					*Syzygophyllia dentata* (D can).
Agaricia agaricites Lamarck	+					Material poor; names drop from list.
undata Lamarck var.	+					
Siderastraea grandis Duncan					+	Type from Jamaica is *Side trea siderea* (Ellis and lander).
crenulata Blainville var. *antillarum* Duncan.	+					This seems to be a synony *S. siderea* (Ellis and So der).
Porites collegniana Michelin	+					Name dropped from list.
Alveopora fenestrata Dana	+					Name dropped from list.

It has appeared that perhaps two distinct geologic horizons we represented by these collections, one of which is the Nivajè shale a another which is represented by the superficial and tufaceous lim stones and the silt of the sandstone plain. The revised list for t Nivajè shale is as follows:

Revised list of species reported by Duncan from the Nivajè shale.

Placotrochus lonsdalei Duncan.
Paracyathus henekeni (Duncan).
Placocyathus variabilis Duncan.

Placocyathus costatus Duncan.
new species.
Pocillopora crassoramosa Duncan.
Stylophora affinis Duncan.
minor Duncan.
new species.
Asterosmilia abnormalis (Duncan).
exarata Duncan.
Dichocoenia tuberosa Duncan.
Antillia dubia (Duncan).
bilobata Duncan.
Orbicella limbata (Duncan).
brevis (Duncan).
cavernosa (Linnaeus).
Thysanus corbicula Duncan.
grandis Duncan.
navicula Duncan.
Maeandra areolata (Linnaeus).
Syzygophyllia gregorii (Vaughan).
dentata (Duncan).

A total of 23 species.

The species from the superficial and tufaceous limestones and the silt of the sandstone plain are as follows:

Revised list of species reported by Duncan from the superficial and tufaceous limestones and the silt of the sandstone plain.

Placocyathus variabilis Duncan.
Stephanocoenia intersepta (Esper).
Dichocoenia tuberosa Duncan.
Orbicella limbata (Duncan).
Orbicella cavernosa (Linnaeus).
Solenastrea bournoni M. Edwards and Haime.
Mussa affinis (Duncan).
Siderastrea siderea (Ellis and Solander).

A total of 8 species, of which 3, those preceded by an asterisk *, are also reported from the Nivajè shale; 6 of these species are either at present living in the West Indies or the fossil specimens are so similar to those of living species that specific discrimination is uncertain (see table on pp. 213, 214 for notes). One species, *Orbicella limbata*, is very similar to one of the growth forms of *Orbicella annularis*. This leaves only one species, *Placocyathus variabilis*, that seems clearly to indicate an older Tertiary age. But it should be added that the species of *Stylophora*, to which Duncan attached the name *raristella*, also indicates a rather old Tertiary formation. Might these two species have been mixed with specimens from a younger formation? Having in

mind the information above stated, I published the suggestion th some of the Santo Domingan fossil corals are perhaps of Pliocene ag

Recently Miss Carlotta J. Maury has submitted to me for study t fossil corals she collected during an expedition to Santo Domin She informs me that the zones on Rio Gurabo are lettered in stra graphically descending series, "A" being at the top and "G" at t base of the section; zone H on Rio Cana is considered to be the sa as zone G on Rio Gurabo. Bluff 1 on Cercado de Mao is correlat by Miss Maury with a part of the Rio Gurabo section above zone and bluff 3 on Cercado de Mao is correlated with that part of the I Gurabo section below zone F.

As regards the corals, the definite stratigraphic tie-point is fou in zone H on Rio Cana, where three species which also occur in t Bowden marl of Jamaica were collected. It has been stated on p 212, 213 of this paper that the Bowden coral fauna is stratigraphica above the Oligocene faunas of Antigua, Bainbridge (Georgia), La (Porto Rico), Empire (Panama), and Tampa (Florida). These San Domingan corals, except those from zone G–H, therefore belo stratigraphically above the horizon of the Bowden marl. In a ma script now almost ready for press I am describing as new six ad tional species of *Placocyathus* from Miss Maury's collection. Th are not entered in the table following.

[1] Washington Acad. Sci. Jour., vol. 5, p. 489, 1915.

Table of species of Santo Domingan corals and their zonal distribution

	Rio Gurabo—Zones.							Rio Cana Zone.	Cercado de Mao—Bluff.		Samba Hills 540+ ft.	The Morro.	Los Quemados limestone.	Notes.
	A and B	B	C	D	E	F	G	H	I	3				
Placocyathus new species					?						+			
barretti Duncan											+		+	
variabilis Duncan			+			+	+							
costatus Duncan								+						
Stylophora granulata Duncan					?									
new species				+										
affinis Duncan				+	+									
Madracis decactis (Lyman)	+								+					Rio Gurabo, zone not stated.
Asterosmilia abnormalis (Duncan)				+	+								+	
Pocillopora crassoramosa Duncan						+								
Stephanocoenia intersepta (Esper)						+			+	+				
Dichocoenia tuberosa Duncan								+						
Antillia dubia (Duncan)								+						Do.
bilobata Duncan				+				+						
Orbicella limbata (Duncan)								+						
bainbridgensis Vaughan?				+										
cavernosa var. *cylindrica* (Duncan)								+						Do.
Solenastrea bournoni (M. Edwards and Haime)											+	+		Do.
Thysanus grandis Duncan				+	+			+						
Syzygophyllia dentata (Duncan)														
gregorii (Vaughan)							+							
Agaricia dominicensis Vaughan					+									
Pavona new species														
new species	+	+												
Siderastrea siderea (Ellis and Solander)								+						
Porites new species		+												
new species										+				

An inspection of the foregoing table shows that at zone H *Orbicell* *cavernosa* and *Solenastrea bournoni*, both now living, were collecte bringing the total of living species from the Bowden horizon up to fou

The following are my conclusions on the geologic age of the cora liferous beds of Santo Domingo:

1. The oldest fauna represented by Miss Maury's collection, zor H on Rio Cana, is that of the Bowden marl. It is somewhat young than the Chipola marl of Florida and is of Burdigalian age accordi to European nomenclature.

2. Zone F is closely related to G and H. It is also probably Burdigalian age, and corresponds to a part of the Alum Bluff form tion of Florida lying above the Chipola marl member.

3. Zone E and D are faunally near the underlying beds and a probably of uppermost Burdigalian or Helvetian age.

4. Zones C to A, inclusive, are probably of Helvetian age.

5. The Santo Domingan coral faunas are younger than the exte sively developed Oligocene coral reefs of Georgia, Florida, Cub Porto Rico, Anguilla, Antigua, and Central America.

6. The presence in Santo Domingo of *Asterosmilia exarata* variet which is also found in the Antigua formation, of a species of *Lepi mussa*, and of *Siderastrea conferta* (Duncan) typical, indicates th there are deposits of middle and upper Oligocene age in San Domingo, but Miss Maury did not make collections of corals fro those horizons.

CUBA.

BARACAO AND MATANZAS.

Fossil corals of Bowden age were collected at two localities namely, station 3476, in a yellow marl at Baracao; and station 34 also in a yellow marl in the gorge of Yumuri River, Matanzas. T species are as follows:

Fossil corals from Baracoa and Matanzas, Cuba.

Name.	Baracoa.	Matanzas	Bow
Stylophora granulata Duncan	×	×	×
Pocillopora baracoäensis Vaughan	×		
Madracis mirabilis (Duchassaing and Michelotti)		×	
Thysanus hayesi Vaughan		×	
Porites baracoäensis Vaughan	×		×
var. *matanzasensis* Vaughan		×	

LA CRUZ MARL.

This name is proposed for the bedded, yellow, argillaceous, a calcareous marl particularly well exposed on the east side of Santi Harbor between Santiago and the Morro. The type exposures a along the railroad eastward from the La Cruz to the crossing of e highway from Santiago to the Morro. The corals collected in t

rmation are listed below. Descriptions of the mollusca by C. W. ooke will appear in a forthcoming publication of the Carnegie Institution of Washington. The corals are as follows:

Fossil corals from the La Cruz marl, Cuba.

Name.	Santo Domingo above zone H.	Santo Domingo zone H	Bowden.	Recent.
lophora affinis Duncan	×			
illopora species				
phanocoenia intersepta (Esper)	×		×	×
bicella limbata (Duncan)	×	×		
enastrea hyades (Dana)				
bournoni M. Edwards and Haime		×		×
ysanus aff. *T. excentricus* Duncan			×	
erastrea siderea (Ellis and Solander)		×	×	×
iopora jacobiana Vaughan				
ites porites (Pallas)				×
astreoides (Lamuck)				×

Of 11 species listed above, 5 are now living in the Antillean region; but of the 8 genera represented, 4, *i. e.* 50 per cent, are now unknown in the Atlantic Ocean. The horizon appears to be above that of the Bowden marl, and to be near zones D and E of the table on page 217. I obtained numbers of poor prints and casts of corals near or at the base of the formation in the vicinity of Santiago. Although they are too poor for determination, they resemble in form the species of *Placocyathus, Asterosmilia, Antillia, Thysanus,* and *Syzygophyllia,* of the Santo Domingan deposits. Similar poor casts and imprints suggest that this is a widely distributed formation in Cuba.

FLORIDA.

ALUM BLUFF FORMATION.

The coral fauna of the Chipola marl, member of Alum Bluff formation is small, comprising four species representing as many genera, namely, *Stylophora, Antillia,* a new genus that resembles a *Thysanus* with a commensal sipunculid worm in its base, and *Goniopora.*

The coral fauna of the Alum Bluff formation is meager. Excluding the Chipola marl member it comprises the following species:

Fossil corals from the Alum Bluff formation.

Name.	Oak Grove.	White Springs.[1]	Tampa brickyard.
rhelia new species	×		
erastrea hillsboroensis Vaughan		×	×
silecensis Vaughan			×
iopora jacobiana Vaughan		×	

[1] For description of the stratigraphic relations of beds at White Springs see Vaughan, T. W., and Cooke, C. V., Correlation of the Hawthorne formation, Washington Acad. Sci. Journ., vol. 4, pp. 250–253, 1914.

Although, in my opinion, the formation in which these corals occur should be referred to the Miocene, I believe it is very low Miocene,

below the Bowden horizon. A recent discovery by Sellards is importance in determining the age of the Alum Bluff formatio The following is a list of the vertebrates:

Parahippus leonensis Sellards.
Merychippus species.
Mesocyon? leonensis Sellards.
Oxydactylus?
Leptomeryx?

Sellards says:

It would seem, therefore, as a whole, that the vertebrate fossils indicate that t Alum Bluff formation is to be referred to the Miocene. The presence of protohipp horses in particular would seem to be decisive as to the age of the formation, excl ing its reference to the Oligocene.

The opinion of Prof. J. C. Merriam on the age indicated by t *Merychippus* is quoted. He says that he would judge the horiz to near the lower portion of the middle Miocene. Later Profes Merriam informed me that he considers the *Merychippus* as of low Miocene (Burdigalian) age.

The evidence in favor of considering the Alum Bluff as of low Miocene age might be greatly multiplied. The presence at O Grove, Yellow River, Florida, of a species of *Astrhelia* closely relat to *A. palmata* (Goldfuss) of the Maryland Choptank and Calv formations suggests Miocene. *Pecten sayanus* Dall indicates M cene. Canu and Bassler are positive that the Bryozoa are of Mioc age. Berry's opinion based on his study of the fossil flora [2] is i incompatible with this interpretation.

MIDDLE AND SOUTH ATLANTIC STATES.

The following is a list of the Miocene species, as far as at pres known:[3]

Miocene corals from the Middle and South Atlantic States.

Name.	Geologic formation.					
	Calvert.	Chop-tank.	St. Marys.	York-town.	Duplin.	Choc hatc
Paracyathus vaughani Gane			×	×	×	
Astrhelia palmata (Goldfuss)	×	×				
Astrangia lineata (Conrad)			×	×		
conradi Vaughan			×			
Septastrea marylandica (Conrad)			×	×		
crassa (Tuomey and Holmes)					×	
Favites vaughani (Gregory)						

[1] Sellards, E. H., Fossil vertebrates from Florida, A new Miocene fauna, Florida Geol. Surv., 8th a. Rept., pp. 83–92, 1916.

[2] Berry, E. W., The physical conditions and age indicated by the flora of the Alum Bluff forma n, U. S. Geol. Survey Prof. Pap. 98–E, pp. 41–59, pls. 7–10, 1916.

[3] Vaughan, T. W., Anthozoa: Maryland Geol. Survey Miocene, pp. 438–448, pls. 122–129, 1904; Th of coral fauna of Carrizo Creek, Imperial County, California, and its significance, U. S. Geol. Survey Pap. 98-T., p. 366, 1917.

Berry has recently reviewed the Miocene Calvert flora of Maryland d Virginia, and expressed the following opinion:[1]

Seven of the Calvert plants, or 26.9 per cent, are common to the Tortonian of Europe, l 10 others, or 38 per cent, are represented in the Tortonian by very similar forms. view of the fact that these floras spread into both regions from a common and equally essible source, as I have just stated, the evidence that the Calvert flora indicates ortonian age is as conclusive as intercontinental correlations can ever be. Compared with other American floras of Miocene age, that of the Calvert has little in common with the described Miocene floras from Colorado, Idaho, Oregon, or California, hich are all lake or river valley floras of moist upland forest types.

Should Berry be correct in his correlation of the Calvert with the uropean Tortonian, there is at present no definitely recognized elvetian Miocene in the Coastal Plain of the United States; and consequently no Helvetian coral-fauna.

COSTA RICA.

Corals representing the Bowden horizon or one very near it were tained in Costa Rica at two localities, viz:

Limon, Colline en démolition," No. 618 of the H. Pittier collection; d at station 6249, Hospital Point, Bocas del Toro. The species m the former of these localities are as follows:

Asterosmilia hilli Vaughan.
Stephanocoenia intersepta (Esper).
Dichocoenia tuberosa Duncan.
Balanophyllia pittieri Vaughan.

Balanophyllia pittieri was obtained at Hospital Point as well as Port Limon.

PANAMA.

The type of *Stylophora portobellensis* Vaughan, from Portobello, s probably collected in the Gatun formation.

COLOMBIA.

Mr. George C. Matson collected at a locality 0.5 kilometer east of Uacuri in association with a fauna representing the Gatun formation specimens of *Septastrea matsoni* Vaughan, which is very nearly lated to *Septastrea marylandica* (Conrad)—a species common in t St. Marys and Yorktown Miocene of Virginia. The available e dence leads to the opinion that the Gatun formation is of Miocene a , and that part of it is of upper Miocene age.

CONCLUDING REMARKS ON THE MIOCENE.

The Gatun formation, the formation next above the Emperador l estone, according to the geologic map, plate 153, occurs only on t north flank of the Isthmus and does not extend from ocean to o an. There is in the Canal Zone no evidence to indicate inter-

[1] U. S. Geol. Survey Prof. Pap. 98-F., p. 66, 1916.

oceanic connection during Miocene time, although there was su connection in other areas not far away, in Nicaragua for instan During the Miocene there was a very weak development of re corals in Central America, the Antilles, and the southeastern Uni States, as the foregoing lists show. The Miocene is characterized the disappearance of many genera of corals that were abundant the middle and upper Oligocene and by the introduction of the mod coral-fauna. However, a number of genera at present known liv only in the Indo-Pacific persisted. These genera are as follows:

Placotrochus.	*Pocillopora.*	*Syzygophyllia.*
Placocyathus.	*Antillia.*	*Pavona.*
Stylophora.	*Favites.*	*Goniopora.*

Of the Miocene genera, *Astrhelia*, *Septastrea*, and *Thysanus* are known living.

PLIOCENE.

CALOOSAHATCHEE MARL, FLORIDA.

The following species of corals have been recognized in the Caloo hatchee marl:

**Archohelia limonensis* Vaughan.
Dichocoenia new species 1.
new species 2.
Meandrina maeandrites (Linnaeus).
Cladocora johnsoni Gane.
Phyllangia floridana Gane.
**Solenastrea hyades* (Dana).
**bournoni* M. Edwards and Haime.
Septastrea crassa (Tuomey and Holmes).
Thysanus species.
Maeandra pliocenica (Gane).
aff. *M. strigosa* (Dana).
aff. *M. clivosa* (Ellis and Solander).
**Siderastrea pliocenica* Vaughan.
**dalli* Vaughan.
**Porites porites* (Pallas).
**furcata* Lamarck.
divaricata Le Sueur.

Those species whose names are preceded by an asterisk are considered in the descriptive part of this paper.

The foregoing list is complete for the Caloosahatchee corals fr Caloosahatchee River and Shell Creek, Florida, except one spe of whose genus I am not sure. There are in the United St National Museum 19 species from the Caloosahatchee marl. these 19 species, 6 and perhaps 8 are also living in the Florid region, while the other species, except those belonging to *Septas*

d *Thysanus*, have close relatives in the present Floridian fauna. have previously pointed out[1] that this fauna contains no genera present confined to the Indo-Pacific, such as *Placotrochus*, *Placothus*, *Stylophora*, *Pocillopora*, *Antillia*, *Syzygophyllia*, and *Goniora*, all of which occur in the West Indian Miocene, and all except e first two also occur in the West Indian Oligocene or Eocene.

LIMON, COSTA RICA.

Certain corals collected in the vicinity of Limon are reputed to me from a bed of Pliocene age. They are as follows:

Madracis mirabilis (Duchassaing and Michelotti).
Archohelia limonensis Vaughan.
Orbicella annularis (Ellis and Solander) var.
cavernosa var. *endothecata* (Duncan).
var. *cylindrica* (Duncan).

Except *Archohelia limonensis*, it appears that these corals might present the Santo Domingan Miocene above the Bowden horizon. e material is not adequate for a positive opinion.

CARRIZO CREEK, CALIFORNIA.

Recently I have described in detail an interesting small reef-al fauna from Carrizo Creek, Imperial County, California.[2] The following table, taken from the paper mentioned, contains e names of the species composing this fauna and of the most arly related species in Florida and the West Indies.

Corals from Carrizo Creek, Cal.

Name.	Most nearly related species in Florida or West Indies.
Emilia carrizensis Vaughan	*Eusmilia fastigiata* (Pallas), Pl, R.
Diocoenia merriami (Vaughan)	*Dichocoenia* species, P; *D. stokesi* Milne Edwards and Haime, Pl, R.
var. *crassisepta* Vaughan	
Siderastrea fairbanksi (Vaughan), typical	
var. *columnaris* (Vaughan)	*Solenastrea hyades* (Dana) and *S. bournoni* Milne Edwards and Haime, P, Pl, R.
var. *normalis* Vaughan	
var. *minor* Vaughan	
Maandra bowersi Vaughan	*Maeandra labyrinthiformis* (Linnaeus), Pl, R.
Siderastrea mendenhalli Vaughan	*Siderastrea dalli* Vaughan, P.
var. *minor* Vaughan	
Siderastrea californica Vaughan	*Siderastrea pliocenica* Vaughan, P.
Porites carrizensis Vaughan	*Porites astreoides* Lamarck, Pl, R.

P, Pliocene; Pl, Pleistocene; R, Recent.

Regarding the geologic age of this fauna, it was said:

he specific affinities of the Carrizo Creek corals are discussed in detail after the descriptions in the systematic part of this paper. The Carrizo Creek species are so near species belonging to the same genera in the Pliocene Caloosahatchee marl of Florida and in the Pleistocene and living reefs of Florida and West Indies that it seems to me they can scarcely be so old as Miocene; lower Pliocene appears to be the maximum age which may be assigned to the fauna.

[1] The reef-coral fauna of Carrizo Creek, Imperial County, California, Prof. Pap. 98-T. p. 366, 1917.
[2] U. S. Geol. Survey Prof. Pap. 98-T, pp. 355-386, pls. 92-102, 1917.

The following is said as to the bearing of this fauna on a possi post-Oligocene interoceanic connection:

That there was interoceanic connection across parts of Central America dur upper Oligocene time and that this connection was terminated in Miocene tim generally admitted. The extinction of Pacific faunal elements in the Gulf of Mex the Caribbean Sea, and the Western Atlantic Ocean has been discussed and su marized on page 366. Was there interoceanic connection during upper Miocene Pliocene time after the sharp differentiation of the Caribbean and Mexican C faunas from the Indo-Pacific faunas, thereby permitting interoceanic faunal mi tion? The discovery of a reef-coral fauna of purely Floridian and Caribbean facie the head of the Gulf of California strongly suggests, if it is not positive proof, that western Atlantic fauna extended from the Atlantic into the Pacific after the fau differentiation had taken place. It is well known that the living reef-coral fauna the Pacific side of Central America is depauperate in comparison with that on Atlantic side. Greater vigor may account for the dominance of the migrant fa over the Pacific fauna, which was finally suppressed, or geologic or other ecol conditions that are not yet understood may have excluded the Pacific fauna from head of the Gulf of California, while they permitted the migration of the Atla fauna into that area.

That the suggested interoceanic connection existed can scarcely be doubted. locate it, in the present state of meager knowledge of the areal and stratigraphic geol of Central America, is not possible. Perhaps it was across the Isthmus of Tehua pec. The problem awaits future investigation.

This fauna differs from the Miocene fauna of the La Cruz marl f Cuba in the absence of genera at present living in the Indo-Paci for instance, *Stylophora*, *Pocillopora*, and *Goniopora*. As none of t Indo-Pacific genera occurs in the Carrizo Creek fauna, and as o genera of Atlantic affinities have been found there, it seems nec sary to infer that the fauna migrated from the Atlantic to the he of the Gulf of California after the Indo-Pacific genera had beco extinct in the Atlantic. This would mean connection between Atlantic and the Gulf of California in very late Miocene or Plioc time.

Attention should here be called to a statement for which I responsible. It is said in the report referred to below[1] that so fossils obtained by Mr. William Palmer in a quarry in Calle Infan Habana, may be of Pliocene age, although it is probable that th are Pleistocene and that other limestone near Habana is perhaps Pliocene age. The material obtained by Mr. Palmer is very po but some specimens are casts of the inside of the calice and the int septal loculi of a large bilobate species of *Antillia*. The species m probably is *A. walli* Duncan of the Bowden marl, but it might *A. bilobata* Duncan; another cast seems to represent a species *Thysanus*; while another is a species of *Syzygophyllia*, probal *S. dentata* (Duncan). One specimen of *Stephanocoenia interse* (Ellis and Solander) is identifiable. The material seems qu clearly to represent either the Bowden or a somewhat higher horiz

[1] Hayes, C. W., Vaughan, T. W., and Spencer, A. C., A geological reconnaissance of Cuba, p. 23, 19

the Miocene. It is not Pliocene, according to our present knowledge Pliocene coral faunas.

PLEISTOCENE.

Only the names of the Pleistocene species considered in this paper given in the following lists:

Pleistocene corals from Mount Hope and Colon, Canal Zone.

Oculina diffusa Lamarck.
varicosa Le Sueur.
Eusmilia fastigiata (Pallas).
Astrangia (*Phyllangia*) *americana* M. Edwards and Haime.[1]
Cladocora arbuscula Le Sueur.
Solenastrea bournoni Milne Edwards and Haime.
Favia fragum (Esper).
Maeandra areolata (Linnaeus).
Manicina gyrosa (Ellis and Solander).
Agaricia agaricites (Linnaeus).
var. *purpurea* Le Sueur.
pusilla Verrill.
Siderastrea radians (Pallas).
siderea (Ellis and Solander).
Meropora muricata (Linnaeus)[1]
palmata (Lamarck) at Colon.
Porites furcata Lamarck.
astreoides Lamarck.
Millepora alcicornis Linnaeus.

It will be remarked in passing that the coral fauna at Mount Hope is a typical inner-flat coral fauna.

Pleistocene specimens were obtained at Monkey Point and Limon, Costa Rica. The list is as follows:

Pleistocene corals from Monkey Point and Limon, Costa Rica.

Name.	Monkey Point.	Limon Moin Hill
Eusmilia fastigiata (Pallas)	×	
Mandra clivosa (Ellis and Solander)	×	
strigosa (Dana)	×	
Manicina gyrosa (Ellis and Solander)		×
Agaricia agaricites var. *crassa* Verrill		×
Siderastrea siderea (Ellis and Solander)	×	
Meandra muricata (Linnaeus)	×	
palmata Lamarck	×	
Porites furcata Lamarck		×

The corals from Monkey Point represent a seaward-facing reef; while those from Moin Hill are more characteristic of inner-flat conditions.

[1] Names added in the proof and not entered in the table of species, pp. 228–237., or the systematic account of the faunas.

SUMMARY OF THE STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF THE TERTIARY AND PLEISTOCENE CORAL-FAUNAS OF CENTRAL AMERICA AND THE WEST INDIES.

1. The upper Eocene coral-fauna of the St. Bartholomew limestone is known in St. Bartholomew, in Jamaica, and on the Pacific side of Nicaragua.

2. No lower Oligocene coral-fauna is at present known in the West Indies or Central America.

3. Rich middle Oligocene coral-faunas are known in Antigua, Porto Rico, Cuba, Georgia (near Bainbridge), Alabama (Salt Mountain), eastern Mexico, Panama, and the Island of Arube. The same fauna is known to be present in Santo Domingo.

4. Upper Oligocene coral-faunas are present in Anguilla, the Canal Zone, Florida (Tampa formation), and there are some of the corals representing the same fauna in Cuba. There seems to be a distinct break between this and the succeeding Miocene faunas.

5. The Bowden, Jamaica, lower Miocene fauna is represented in Santo Domingo, Cuba, and Costa Rica. This fauna is probably younger than the coral-fauna of the Alum Bluff formation in Florida.

6. A closely related but higher Miocene fauna is present in Santo Domingo and Cuba. It seems probable that this fauna is geologically older than the coral fauna of the Maryland and Virginia Miocene.

7. The presence at Usiacuri, Colombia, of a species of *Septastrea* very closely related to *S. marylandica* of the St. Marys and Yorktown Miocene of Virginia, suggests the presence in northern South America of a middle or an upper Miocene coral fauna.

8. There is a moderately rich Pliocene fauna in the Caloosahatchee marl of Florida, and this fauna appears to be represented at Limon, Costa Rica.

9. Pleistocene reefs are extensively developed in Central America, the West Indies, and Florida.

10. Living reefs exist in the same areas in which there are Pleistocene reefs.

11. The periods of reef-coral development are as follows:

(*a*) Upper Eocene St. Bartholomew limestone, weak development.

(*b*) Middle Oligocene, the greatest known development of American coral-reefs.

(*c*) Upper Oligocene, considerable development of reefs.

(*d*) Miocene, weak development of reefs.

(*e*) Pliocene, weak development of reef-corals in Florida.

(*f*) Pleistocene, extensive development of reefs.

(*g*) Recent, extensive development of reefs.

12. Periods of connection between the Atlantic and Pacific oceans are as follows:

(*a*) Upper Eocene.

(*b*) Middle and upper Oligocene and lower Miocene.

(*c*) A connection, probably narrow, in very late Miocene or in Pliocene time.

TABLE OF STRATIGRAPHIC

Name of species.	Eocene—Brito formation, Nicaragua.	Oligocene.		
		Horizon of Antigua formation.	Culebra formation, Canal Zone.	Horizon Anguill formatio
Stylophora imperatoris Vaughan			Gaillard Cut; 1½ mi. S. Monte Lirio.	Anguilla.
panamensis Vaughan				
affinis Duncan				
portobellensis Vaughan				
goethalsi Vaughan			1½ mi. S. of Monte Lirio.	
macdonaldi Vaughan				
granulata Duncan				
canalis Vaughan				
ponderosa Vaughan		Alabama; Antigua.		
Pocillopora arnoldi Vaughan				
baracoënsis Vaughan				
guantanamensis Vaughan		Near Guantanamo, Cuba.		
Madracis mirabilis (Duchassaing and Michelotti).				
Astrocoenia d'achiardii Duncan	Also St. Bartholomew.			
guantanamensis Vaughan		Antigua; near Guantanamo, Cuba; Tonosi, Panama.		
incrustans (Duncan)				
decaturensis Vaughan		Bainbridge, Ga.; Antigua; near Guantanamo, Cuba.		
meinzeri Vaughan		Near Guantanamo, Cuba.		
portoricensis Vaughan		Antigua; Lares P. R.		
Stylocoenia pumpellyi (Vaughan)		Bainbridge, Ga.; Antigua.		
Oculina diffusa Lamarck				
varicosa Le Sueur				
Archohelia limonensis Vaughan				
Asterosmilia hilli Vaughan				
Stephanocoenia intersepta (Esper)				
Dichocoenia tuberosa Duncan				
Eusmilia fastigiata (Pallas)				
Cladocora arbuscula (Le Sueur)				
Orbicella annularis (Ellis and Solander).				
limbata (Duncan)				

OGRAPHIC DISTRIBUTION OF SPECIES.

ligocene—ontinued. / mperador imestone, anal Zone.	Miocene—Horizon of Bowden marl, etc.	Pliocene.	Pleistocene.	Recent.	Remarks.
pire: Rio gua Salud.					
npire					
	Santo Domingo; Santiago, Cuba. (?)				Porto Bello; probably Gatun formation.
npire					
npire; Rio gua Salud.					
	Matanzas and Baracoa, Cuba; Rio Gurabo, St. Domingo, etc.				
npire					
npire					
	Baracoa, Cuba				
	Matanzas, Cuba.	Colon, Costa Rica.		Caribbean region.	
					Upper Eocene of St. Bartholomew.
o Agua Salud.					
			Mt. Hope, C. Z.	Florida; West Indies, etc.	
			Mt. Hope, C. Z.	do	
		Limon, C. R.; Caloosahatchee marl, Florida.			
	Limon, C. R.; Bowden, Jamaica.				
	Bowden, Jamaica; Limon, C. R.; Santo Domingo; Santiago, Cuba.		West Indian region.	West Indies, Bermuda, etc.	
	Limon, C. R.; Santo Domingo.				Very near the Pleistocene and living *D. stokesi* M. Edwards and Haime of the West Indies, Florida, etc.
			Mt. Hope, C. Z.; Monkey Pt., C. R.; W. I.	West Indies; Florida, etc.	
			Mt. Hope, C. Z.	do	
		Limon, C. R.	W. I.; Fla.; etc.	do	
	Santo Domingo, Cuba.				

TABLE OF STRATIGRAPHIC AND GEOGRAP

Name of species.	Eocene—Brito formation, Nicaragua.	Oligocene.		
		Horizon of Antigua formation.	Culebra formation, Canal Zone.	Horizon o Anguilla formation
Orbicella imperatoris Vaughan				Anguill Cuba.
antillarum (Duncan)				
altissima (Duncan)				
cavernosa (Linnaeus)				
var. *endothecata* (Duncan)				
var. *cylindrica* (Duncan)				
aperta (Verrill)				
bainbridgensis Vaughan		Bainbridge, Ga.		
costata (Duncan)		Antigua; Lares, P. R.	Las Cascadas	Anguilla
canalis Vaughan				Anguilla
tampaensis Vaughan				
var. *silecensis* Vaughan				
brevis (Duncan)				
insignis (Duncan)		Antigua; Arube.		
intermedia (Duncan)		Antigua		
gabbi Vaughan				
irradians (M. Edwards and Haime).				
Solenastrea hyades (Dana)				
bournoni M. Edwards and Haime.				
Septastrea matsoni Vaughan				
Antiguastrea cellulosa (Duncan)		Antigua; P. R.; Cuba; Ga.; eastern Mex.; Arube.		Anguil Tampa, Florida.
var. *curvata* (Duncan)		Antigua		
var. *silecensis* Vaughan		Bainbridge, Ga.; Antigua.		
elegans (Reuss)				
alveolaris (Catullo)				
Stylangia panamensis Vaughan				
Favia fragum (Esper)				
macdonaldi Vaughan		Tonosi, Panama; Antigua.		
Favites mexicana Vaughan		Eastern Mexico.		
polygonalis (Duncan)		Antigua; Bainbridge, Ga.		
Goniastrea canalis Vaughan				
Macandra antiguensis Vaughan		Antigua; Tonosi, Panama.		
portoricensis Vaughan		Lares, Porto Rico.		
dumblei Vaughan		Eastern Mex		
areolata (Linnaeus)				

STRIBUTION OF SPECIES—Continued.

Oligocene—Continued.	Miocene—Horizon of Bowden marl, etc.	Pliocene.	Pleistocene.	Recent.	Remarks.
Emperador Limestone, Canal Zone.					
mpire and ear Miraores.					
					Montserrat, geologic horizon unknown.
					St. Croix, Trinidad; probably about the horizon of the Antigua formation.
			West Indies; Florida.	West Indies; Florida; Brazil.	
	Santo Domingo.	Limon, C. R.			
	do	do			
				Brazil.	
	? Santo Domingo.				
mpire					
					Tampa, Fla.; about the horizon of the Anguilla formation.
					Do.
					Santo Domingo, Nivajè shale. Horizon unknown.
					Santo Domingo; horizon unknown.
					Lutetian (Eocene); Rupelian (Oligocene) of Veneto, Italy.
	Santiago and Ciénaga, Cuba.	Caloohatchee marl, Fla.	West Indies; Florida.	West Indies; Florida.	
	Santiago, Cuba; Santo Domingo.	do		do	
	Usiacuri, Colombia.				Formation in part the same as the Gatun formation, C. Z.
					Byram marl, Miss.
					Rupelian (Oligocene), Venetio, Italy.
					Rupelian (Oligocene), Venetio, Italy.
mpire, C. Z.			Mt. Hope, C.Z.; W.I.; Fla.	W. I.; Fla.; Bermudas; Azores; St. Vincent.	
mpire, C. Z.					
			Mt. Hope, C.Z.; W. I.; Fla., etc.	W. I.; Fla.; etc.	

TABLE OF STRATIGRAPHIC AND GEOGRAP

Name of species.	Eocene—Brito formation, Nicaragua.	Oligocene.		
		Horizon of Antigua formation.	Culebra formation, Canal Zone.	Horizon Anguill formatio
Maeandra clivosa (Ellis and Solander)				
strigosa (Dana)				
Leptoria spenceri Vaughan		Rio Canapu, Cuba; Antigua?.		
Manicina gyrosa (Ellis and Solander)				
willoughbiensis Vaughan		Antigua		
Thysanus excentricus Duncan				
hayesi Vaughan				
Syzygophyllia hayesi Vaughan	Brito			
Trochoseris meinzeri Vaughan		Guantanamo; Tonosi, Panama.		
Agaricia agaricites (Linnaeus)				
var. *purpurea* Le Sueur				
var. *crassa* Verrill				
var. *pusilla* Verrill				
anguillensis Vaughan				Anguilla.
dominicensis Vaughan				
Pavona panamensis Vaughan				
Leptoseris portoricensis Vaughan		Lares, P. R.		
Pironastraea anguillensis Vaughan		Lares road, Zone C, P. R.		Anguilla.
antiguensis Vaughan		Antigua; Guantanamo, Cuba.		
Siderastrea pariana (Duncan)				
radians (Pallas)				
stellata Verrill				
confusa (Duncan)				
pourtalesi Vaughan				
pliocenica Vaughan				
hillsboroensis Vaughan				
siderea (Ellis and Solander)				
var. *dominicensis* Vaughan				
silccensis Vaughan				Anguilla.
dalli Vaughan				

)STRIBUTION OF SPECIES—Continued.

)ligocene—Continued.	Miocene—Horizon of Bowden marl, etc.	Pliocene.	Pleistocene.	Recent.	Remarks.
Emperador Limestone, Canal Zone.					
.....	.....	.....	Monkey Pt., C. R.; W. I.; Fla.	.....do.....	
.....	.....	.....	.....do.....	.....do.....	
.....	.....	.....	.....	.....	
.....	.....	.....	Mt. Hope, C.Z.; Moin Hill, C. R.; W. I.; etc.	Fla.; W.I.; etc.	
.....	Santiago, Cuba; Bowden, Jamaica.	.....	.....	.....	
.....	Matanzas, Cuba.	.....	.....	.....	
.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	
.....	.....	.....	Mt. Hope, C.Z.; W. I.; Fla.; etc.	W. I.; Fla.; etc.	
.....	.....	.....	Mt. Hope, C.Z..	.....do.....	
.....	.....	.....	Moin Hill, C. R.	Especially abundant east side of Andros Is., Bahamas.	
.....	.....	.....	Mt. Hope, C.Z..	Colon, C. Z.....	
.....	.....	.....	.....	.....	
.....	Santo Domingo; Matanzas, Cuba.	.....	.....	.....	
npire.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	St. Croix, Trinidad; probably nearly the same as the Antigua horizon.
.....	.....	.....	Mt. Hope, C.Z.; W. I.; Fla.; etc.	W. I.; Fla.; Bermudas.	
.....	.....	.....	.....	Brazilian reefs.	
.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	Santo Domingo; horizon unknown.
.....	.....	Caloosahatchee marl, Fla.	.....	.....	
.....	.....	.....	.....	.....	Chattahoochee, Tampa, and Alum Bluff formations, Florida and Georgia.
.....	Bowden, Jamaica; Santo Domingo; Santiago, Cuba.	.....	Mt. Hope, C.Z.; Monkey Pt., C. R.; W. I.; Fla.	W. I.; Fla.; etc.	
.....	.....	.....	.....	Haiti.....	
.....	.....	.....	.....	.....	Do.
.....	.....	Caloosahatchee marl, Fla.	.....	.....	

TABLE OF STRATIGRAPHIC AND GEOGRAPHIC

Name of species.	Eocene—Brito formation, Nicaragua.	Oligocene.		
		Horizon of Antigua formation.	Culebra formation, Canal Zone.	Horizon Anguilla formation.
Siderastrea conferta (Duncan)		Antigua; Lares, P. R.	Las Cascadas	Anguilla
Cyathomorpha rochettina (Michelin)				
hilli Vaughan		Antigua		
browni Vaughan		do		
belli Vaughan		do		
splendens Vaughan		do		
anguillensis Vaughan				Anguilla
roxboroughi Vaughan				do
antiguensis (Duncan)		Antigua; Lares, P. R.; Guantanamo, Cuba; eastern Mexico.		
tenuis (Duncan)		Antigua; Lares, P. R.; Rio Canapu and Guantanamo.		
Diploastrea heliopora (Lamarck)				
crassolamellata (Duncan)		Antigua; Lares, P. R. (Zone C); Cuba; Bainbridge, Ga.; Tonosi, Panama.		
var. *magnifica* (Duncan)		Antigua Lares, P. R.; Guantanamo, Cuba; Bainbridge, Ga.		
var. *nugenti* (Duncan)		Antigua		
Blanophyllia pittieri Vaughan				
Acropora panamensis Vaughan		Antigua		
saludensis Vaughan		do		
muricata (Linnieus)				
palmata (Lamarck)				
Astreopora goethalsi Vaughan				
antiguensis Vaughan		Antigua; Bainbridge, Ga.	1½ mi. S. of Monte Lirio.	
portoricensis Vaughan		Lares, P. R.		
Actinacis alabamiensis Vaughan		Ala.; Bainbridge, Ga.; Antigua.		
Goniopora hilli Vaughan				
panamensis Vaughan				Anguilla
decaturensis Vaughan		Bainbridge, Ga.; Guantanamo, Cuba.		
regularis (Duncan)		Antigua; P. R.; Aruba.		
var. *microscopica* (Duncan)		Antigua		
jacobiana Vaughan				
imperatoris Vaughan				Anguilla
canalis Vaughan				do
portoricensis Vaughan		Lares, P. R.; Antigua.		

STRIBUTION OF SPECIES—Continued.

Oligocene—Continued. Emperador limestone, Canal Zone.	Miocene—Horizon of Bowden marl, etc.	Pliocene.	Pleistocene.	Recent.	Remarks.
					Lattorfian and Rupelian (Oligocene) of Veneto, Italy.
				East coast of Africa to Fiji Islands.	
	Limon and Hospital Pt., C. R.				
o Agua Sa-ıd, C. Z.					
o Agua Sa-ıd and Em-ire, C.Z.					
			Monkey Pt. and Moin Hill, C. R.; W. I.; Fla.; etc.	W.I.; Fla.; etc.	
			Monkey Pt., C. R.; Colon, C. Z.	W.I.; Fla.; etc.	
npire					
npire					
.do					
	Santiago, Cuba; White Springs, Fla.				
npire					
.do					

TABLE OF STRATIGRAPHIC AND GEOGRAP

Name of species.	Eocene—Brito formation, Nicaragua.	Oligocene.		
		Horizon of Antigua formation.	Culebra formation, Canal Zone.	Horizon c Anguilla formatian
Goniopora clevei Vaughan		Antigua		Anguilla
cascadensis Vaughan		do	Las Cascadas	do
Porites porites (Pallas)				
furcata Lamarck				
baracoäensis Vaughan				
var. *matanzasensis* Vaughan				
douvillei Vaughan				
toulai Vaughan				
astreoides Lamarck				
panamensis Vaughan				
anguillensis Vaughan				Anguilla
(*Synaræa*) *howei* Vaughan				
macdonaldi Vaughan				Anguilla
Millepora alcicornis Linnaeus				

ISTRIBUTION OF SPECIES—Continued.

Oligocene—Continued. Emperador Limestone, Canal Zone.	Miocene—Horizon of Bowden marl, etc.	Pliocene.	Pleistocene.	Recent.	Remarks.
upire					
	Santiago, Cuba.		W. I	W.I.; Fla.; etc.	
			Mt. Hope, C. Z.; Moin Hill, C. R.	do	
	Baracoa, Cuba; Bowden, Jamaica.				
	Matanzas, Cuba				
upire					
do					
	Santiago, Cuba.		Mt. Hope, C. Z.; W. I.; Fla.	W. I.; Fla.; Bermudas; Brazil, etc.	
upire					
do					
do					
do					
			Mt. Hope, C. Z.	W. I.; Fla.; etc.	

CONDITIONS UNDER WHICH THE WEST INDIAN, CENTRAL AMERICAN, AND FLORIDIAN CORAL REEFS HAVE FORMED, AND THEIR BEARING ON THEORIES OF CORAL-REEF FORMATION.

A brief review of the results obtained from a study of American Tertiary and post-Tertiary corals in their relation to the larger problem of coral-reef formation in general will now be given. In a paper recently published[1] I stated that in my opinion coral reefs should be studied from at least the following standpoints:

1. The corals themselves, to ascertain the ecologic conditions under which they live or lived, and to distinguish the calcium carbonate secreted by corals from that contributed through other agencies.

2. A complex of geologic processes operating in the area must be studied, analyzed, and evaluated—among these are the agencies other than corals whereby calcium carbonate may be taken from the sea water, the probability of the solvent action of sea water on calcium carbonate, the effects of winds, currents, and waves in building, shaping, and destroying banks, and in submarine planation.

3. The stratigraphic and structural geology of the area, including a careful study of the origin of the sedimentary rocks with which corals are associated.

4. The physiography, especially that of the shore line, that of the land area adjacent to the shore, and that of the sea bottom from the shore to abyssal depths.

In the subsequent discussion, after defining coral reef, brief attention will be given to the following topics: (1) The general ecology of reef-forming corals; (2) the more striking hypotheses of the formation of coral-reefs; (3) the conditions under which the American Tertiary and Pleistocene reefs have formed and their importance as constructional geologic agents; (4) the conditions under which the living reefs of the same area formed and their importance as constructional agents; (5) coral reefs of the Pacific Ocean and comparison of them with the American fossil and living reefs; (6) summary of conclusions.

It is needless to say that, as an elaborate discussion of the subjects mentioned would require a large volume, it is possible in the present connection to give only summary statements.

Definition of the Term "Coral Reef."

As definitions are essential in this as in other discussions, the expression "coral reef" will be defined as follows:

A coral reef is a ridge or mound of limestone, the upper surface of which lies or lay at the time of its formation, near the level of the sea, and is predominantly composed of calcium carbonate secreted by organisms, of which the most important are corals.[2]

[1] Some shoal-water corals from Murray Island (Australia), Cocos-Keeling Islands, and Fanning Island, Carnegie Inst. Washington Pub. 213, p. 54, 1918.

[2] Vaughan, T. W., Physical conditions under which Paleozoic coral reefs were formed, Bull. Geol. Soc. America, vol. 22, p. 238, 1911.

Frequently it is difficult to decide whether or no to apply the designation "coral reef" to richly coralliferous deposits that are obviously bedded. However, I am applying it wherever corals of reef facies are sufficiently abundant to have formed appreciable rugosities on the sea bottom, although the deposits are bedded.

Reefs predominatly formed by calcareous algae should be designated "nullipore" or "Lithothamnium reefs." However, where the proportion of these organisms to corals is so nearly the same that only exact computation will decide between the two, such a reef may be designated "coral." The expression "reef coral" will be applied to corals of the facies usual in reefs; and "coralliferous limestone" or "coralliferous beds" will be applied where corals are present, although they may be rare. Rock predominantly composed of the shells of mollusks, of the tests of foraminifera and bryozoa, and of chemically precipitated calcium carbonate are excluded from the category "coral reefs."

The restricted use of the term "coral reef" in this paper will probably be disapproved by a considerable number of investigators, but in my opinion it is essential to clear thinking. Limestones are initially formed by one of two processes, namely, (1) through chemical precipitation either by inorganic or organic agencies that lead to supersaturation of water with reference to calcium carbonate ($CaCO_3$), (2) through the activity of organisms that cause the precipitation of calcium carbonate ($CaCO_3$) in contact with their soft tissues. Corals belong to a group of organisms that secrete calcium carbonate ($CaCO_3$), that is, cause the precipitation of calcium carbonate ($CaCO_3$) in contact with their soft tissues. Every kind of coral-water calcium-carbonate deposit has been called "coral rock": the molluscan-shell sands of the Bermudas, the chemically precipitated calcium carbonate of the oolites of Florida and the Bahamas, and limestones composed of the remains of Foraminifera and Bryozoa. The terms coral sand and coral mud have been applied to bottom-deposits in which there is no coral. To apply the term "coral rock" or "coral-reef rock" to all the kinds of limestones indicated would at the present time, in my opinion, be willful mental obfuscation. The study of the origin of limestones and the classification of limestones according to the source of their ingredients constitute a scientific problem of great geologic importance, and I believe it a scientific duty to break away from a usage that in *most* instances concealed scientific fact.

The importance of the distinction between "reef" and the material lying between a "reef" and the shore is particularly discussed on page 249.

ECOLOGY OF REEF-FORMING CORALS.

This subject has received the attention of very many investigato and most of the broad principles have long been known. Darw clearly recognized the difference in growth-form of exposed-re corals and the corals that grow in the lagoons.[1] This subject h been discussed at great length by subsequent investigators, of who I am one, but although facts have been presented in a more or le statistical way, the principle of adaptation of growth form to en ronment was as clearly perceived by Darwin as it is by anyone t day. Dana's conclusions on the relations of corals to the tempe ture of the ocean have been modified in only a subordinate way. is scarcely known who first recognized the polymorphism of spec of corals according to difference in habit. The recognition of su vegetative adaptation was at least foreshadowed by Klunzinger a Pourtalès. Brook clearly recognized the principle, and during m recent years it has been elaborately discussed by Gardiner, V Marenzeller, Wood Jones, and many others, including myself. T literature on coral ecology is enormous, and probably the ecolo relations of no other group of marine organisms are so well known.

Recently I have published two summaries on the physical con tions under which coral reefs form,[2] and have discussed in detail t temperature relations of coral reefs in a paper entitled Temperat of the Florida Coral-reef Tract.[3] Dr. A. G. Mayer has given i portant information on some of the subjects of coral ecology i paper entitled Ecology of the Murray Island coral reef;[4] and have given considerable data on the relation between the growt form of colonies and habitat in my monograph, Some shoal-wa corals from Murray Island (Australia), Cocos-Keeling Islands, a Fanning Islands.[5] The last-mentioned paper contains a compl bibliography of my publications on corals and coral reefs up March, 1917.

In the second of my papers referred to in the preceding paragrap I state on page 99:

> The conditions necessary for vigorous coral-reef development may be summari as follows: (1) Depth of water, maximum, about 45 meters; (2) bottom firm or roc without silty deposits; (3) water circulating, at times strongly agitated; (4) an ab dant supply of small animal plankton; (5) strong light; (6) temperature, annual m mum not below 18° C.; (7) salinity between about 27 and 38 parts per thousand.

To this should be added the statement that the mean temperat of the coldest month must not be lower than about 21° C.

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[1] Structure and distribution of coral reefs, ed. 3, pp. 1–19, 1889.

[2] Vaughan, T. W., Physical conditions under which Paleozoic coral reefs were formed, Geol. Soc. A Bull., vol. 22, pp. 238–252, 1911; The results of investigations of the ecology of the Floridian and Baha shoal-water corals, Nat. Acad. Sci. Proc., vol. 2, pp. 95–100, 1916. See also Corals and the formati coral reefs, Smithsonian Ann. Rept. for 1917 (in press).

[3] Carnegie Inst. Washington Pub. 213, pp. 321–339, 1918.

[4] Idem, pp. 1–48, pls. 1–19, 1918.

[5] Idem, pp. 49–233, pls. 20–93, 1918.

Wherever there are well-developed fossil coral reefs it seems safe infer that the physical conditions above enumerated prevailed. is unnecessary to discuss separately each item entered under No. of the summary statement of the periods of coral reef develop-ent on page 226. During upper Oligocene time (the time of the position of the upper part of the Chattahoochee formation) tropical nditions extended in Georgia as far north as latitude 32° 45′.

Hypotheses of the Formation of Coral-Reefs.

During the past few years elaborate reviews of theories of the forma-on of coral reefs have been published by Prof. W. M. Davis, the ger of which are referred to in the footnote below.[1] These reviews e valuable in presenting most of the important coral-reef theories, they are understood by a physiographer, who is convinced of the equacy of the Darwinian hypothesis. Numbers of complex phe-mena associated with coral reefs are not considered, and his pre-ntations are not in all respects satisfying. Prof. R. A. Daly has viewed the literature on coral-reef theory, particularly from e standpoint of an adherent of the glacial-control hypothesis.[2] he literature on coral reefs is so enormous, that in the present paper nsideration can be given only to certain papers that largely deal with ral-reef hypotheses or that contain information on areas herein dis-ssed. The limitations of space cause me to omit references to any papers of much merit.

Three kinds of coral reefs are generally recognized, namely: (1) inging or shore reefs which, as the name indicates, occur along the and line; (2) barrier reefs which occur at variable distances shore and have lagoons from 1 or 2 to as much as 30 or even 40 thoms in depth between them and the strand line; (3) atolls, which e ring-like and inclose lagoons above whose surface no land-masses importance protrude.

As the relations of barrier reefs and atolls to the platforms above nich they rise constitute in the opinion of geologists the essential rt of the theory of the development of Recent reefs, the warfare coral reef theory has been waged over the interpretation of these lations, which are the conditions of changing or changed position the strand line and the part played by reef-forming organisms constructional agents.

1. According to Darwin [3] and Dana,[4] corals first form a fringing ef off the *sloping* shore of a subsiding land area; the reef grows

[1] Davis, W. M., Dana's confirmation of Darwin's theory of coral reefs, Amer. Journ. Sci., ser. 4, vol. 35, 173-188, 1913; The home study of coral reefs, Amer. Geogr. Soc. Bull., vol. 46, pp. 561-577, 641-654, 721-739, ; A Shaler memorial study of coral reefs, Amer. Journ. Sci., ser. 4, vol. 40, pp. 223-271, 1915; Problems ciated with study of coral reefs, Scientific Monthly, vol. 2, pp. 213-333, 479-501, 557-512, 1916. Also eral short articles in Nat. Acad. Sci. Proc., vols. 1, 2, 1915-1917.

[2] Daly, R. A., The glacial-control theory of coral reefs, Amer. Acad. Arts and Sci., vol. 51, pp. 157-251, 1915.

[3] Darwin, C. R., Structure and distribution of coral reefs, ed. 3, fig. 5, p. 134, fig. 6, p. 137, 1899.

[4] Dana, J. D., Corals and coral reefs, ed. 3, pp. 263, 267, 1890.

upward at such a rate that its top remains near the surface of tl water and through retreat of the shore it is converted into a barrie Continued subsidence, where the inclosed land area is an inlan may result in the production of an atoll circumscribing a lago without any land mass projecting above the water level. But tl is not all. The Darwinian hypothesis involves more than me

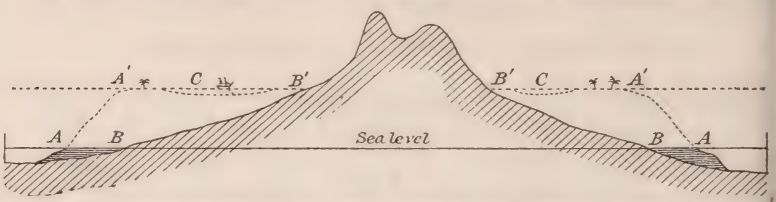


FIG. 4. COPY OF DARWIN'S FIGURE ILLUSTRATING CONVERSION OF A FRINGING INTO A BARRIER RE ACCORDING TO HIS HYPOTHESIS. *AA*—OUTER EDGE OF THE REEF AT THE LEVEL OF THE SEA. *B* SHORES OF THE ISLAND. *A'A'*—OUTER EDGE OF THE REEF, AFTER ITS UPWARD GROWTH DURIN PERIOD OF SUBSIDENCE. *CC*—THE LAGOON-CHANNEL BETWEEN THE REEF AND THE SHORES OF NOW ENCIRCLED LAND. *B'B'*—THE SHORES OF THE ENCIRCLED ISLAND. N. B.—IN THIS, AND FOLLOWING CUT, THE SUBSIDENCE OF THE LAND COULD ONLY BE REPRESENTED BY AN APPARENT R IN THE LEVEL OF THE SEA.

subsidence and the conversion of a fringing into a barrier reef. also attempts to account for extensive submarine platforms assuming that they have been built upon *sloping* basements throu agencies dependent on the presence of reefs. (See text-figs. 4, 5, Dana's interpretation [1] is essentially that of Darwin.

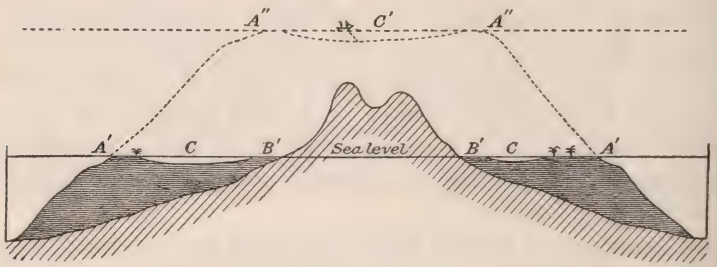


FIG. 5. COPY OF DARWIN'S FIGURE ILLUSTRATING CONVERSION OF A BARRIER REEF INTO AN ATOLL, CORDING TO HIS HYPOTHESIS. *A'A'*—OUTER EDGES OF THE BARRIER-REEF AT THE LEVEL OF THE S THE COCOA-NUT TREES REPRESENT CORAL-ISLETS FORMED ON THE REEF. *CC*—THE LAGOON-CHANN *B'B'*—THE SHORES OF THE ISLAND, GENERALLY FORMED OF LOW ALLUVIAL LAND AND OF CORAL DE TUS FROM THE LAGOON CHANNEL. *A''A''*—THE OUTER EDGES OF THE REEF, NOW FORMING AN ATC *C'*—THE LAGOON OF THE NEWLY FORMED ATOLL. ACCORDING TO THE SCALE THE DEPTH OF THE LAG AND OF THE LAGOON CHANNEL IS EXAGGERATED.

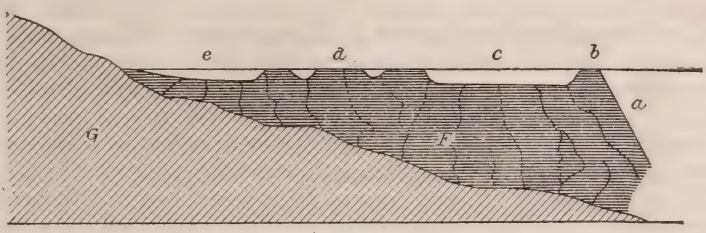
That Darwin considered an alternative hypothesis is shown by t following quotation:

I may here observe that a bank either of rock or of hardened sediment, level wi the surface of the sea and fringed with living coral, would be immediately convert into an atoll, without passing, as in the case of a reef fringing the shore of an isla through the intermediate form of a barrier reef.

[1] Corals and coral islands, ed. 3, figs. pp. 263, 267, 1890.

He adds, however,

* * but as we have seen, the larger groups of atolls in the Pacific and Indian eans have not been formed on banks of this nature. [1]



. 6. REPRODUCTION OF J. B. JUKES' SECTION ACROSS THE GREAT BARRIER REEF OF AUSTRALIA. *a*. EA OUTSIDE THE BARRIER, GENERALLY UNFATHOMABLE. *b*. THE ACTUAL BARRIER. *c*. CLEAR CHAN-EL INSIDE THE BARRIER, GENERALLY ABOUT 15 OR 20 FATHOMS DEEP. *d*. THE INNER REEF. *e*. SHOAL HANNEL BETWEEN THE INNER REEF AND THE SHORE. *F*. THE GREAT BUTTRESS OF CALCAREOUS ROCK, ORMED OF CORAL AND THE DETRITUS OF CORALS AND SHELLS. *G*. THE MAINLAND, FORMED OF GRANITES ND OTHER SIMILAR ROCKS.

2. The first important protest against the Darwinian explanation as by Carl Semper,[2] who, in 1863, after studies in the Pelew Islands, lvanced the hypothesis that atolls could be formed in areas of evation by the solution of the interior of preexistent limestone asses, and that solution, erosion by currents, and wave-cutting uld develop platforms behind fringing reefs, thus transforming a inging into a barrier reef.

3. Murray [3] introduced the idea of banks being built upward showers of the remains of pelagic organisms until the bathymetric ne of reef-forming organisms is reached, and he called attention to e cutting of volcanic islands down to wave base. His theory has en briefly summarized by himself in the following words:[4]

That when coral plantations build up from submarine banks they assume an atoll m, owing to the more abundant supply of food to the outer margin, and the removal dead coral rock from the interior portions by currents and by the action of the rbonic acid gas dissolved in sea-water.

That barrier reefs have been built out from the shore on a foundation of volcanic bris or on a talus of coral blocks, coral sediment, and pelagic shells, and the lagoon annel is formed in the same way as a lagoon.

That it is not necessary to call in subsidence to explain any of the characteristic atures of barrier reefs or atolls, and that all these features would exist alike in areas slow elevation, of rest, or of slow subsidence.

4. H. B. Guppy in 1890 published the following important opinion garding the relations of barrier reefs to submarine plateaus or dges:[5]

I have now gone far enough to establish the probability, judging from the instance of e Australian Barrier-reef, that reefs of this class are in reality, and not in appearance,

Structure and distribution of coral reefs, ed. 3, pp. 138, 139.

Semper, Carl, Reisebericht, Zeitsch. für wiss. Zoologie, vol. 13, pp. 563-569, 1863.

Murray, John, On the structure and origin of coral reefs and islands, Roy. Soc. Edinburgh Proc., . 10, 1879-80, pp. 505-518, 1880.

Idem, p. 517.

Guppy, H. B., The origin of coral reefs, Victoria Inst. Journ. Trans., vol. 23, pp. 51-61, 1890.

situated on the border of a submarine plateau or ledge. Such a position, accordi to the explanation of barrier-reefs, first advanced by LeConte, and supported myself, presents the most favorable conditions for reef growth, the corals being limi on the outside by the depth, and on the inside by the sediment in the water. T influences of food-supply and currents act subsequently as auxiliary causes.

What, then, is the explanation of the submarine ledge? The supposition that i a continuation of the land slope is at once negatived by the fact that the slope of land in the reef-encircled islands of the Pacific is usually 6 degrees or 7 degrees, sor times only 3 degrees or 4 degrees, but often as much as 10 degrees, or 12 degrees, wh the submarine ledge, when stripped of reefs and defined by the 100-fathom line, wo possess a scarcely recognizable inclination, represented by a fraction of a deg It will be found, however, when we examine the contour of such an island as Vanik that the distance of the barrier-reef from the coast may vary according to the slop the land. Thus, on the west side of this island, the average angle of the land slop 6 degrees, and the distance of the barrier reef about $2\frac{1}{2}$ miles. On the north side inclination of the land is between 11 degrees and 12 degrees, and the barrier ree rather over a mile distant. This is just what we should expect. The more gradual land slope, the broader will be the submarine ledge, cut out in the course of ages the action of the sea, and the more distant will be the barrier reef that has grown along its margin. This I believe to be the true explanation of the position of bar reefs. A submarine ledge is in the first place necessary; and, since the sediment mud in the shallower waters on the ledge repress the growth of corals, reefs naturally spring up toward the margin of the ledge, where the water is clearer where the depth is within that of the reef-coral zone.[1]

5. Admiral Sir W. J. L. Wharton[2] explained the uniform depth atoll lagoons, whose edges are in various degress encircled by growi coral, by considering that the corals grow upon foundations that the bases of volcanic islands that have been reduced by wave act to wave base.

6. Alexander Agassiz[3] found older limestone under the recent re in many areas investigated by him. He explained atolls by the so tion and erosion of the interior of preexisting limestone masses a ascribed the formation of the platforms of barrier reefs to mar erosion without change of sea level.

7. Andrews[4] pointed out that the platform of the Great Barr Reef of Australia has been submerged at a relatively recent date a that it continues southward beyond the reef, and he inferred that o a minor part of the platform is "formed of coral growth."

8. The opinions of Stanley Gardiner[5] are closely in accord with th of Semper, Murray, Wharton, and Agassiz. According to him s marine planation is effective to depths as great as 200 fathoms.

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[1] Guppy, H. B., The origin of coral reefs, pp. 60, 61.

[2] Wharton, W. J. L., Foundations of coral atolls, Nature, vol. 55, pp. 390–393, 1897.

[3] Agassiz, Alexander, The Coral reefs of the Tropical Pacific, Mem. Mus. Comp. Zool., vol. 27, 1 v. text, 3 vols. of pls., 1903.

[4] Andrews, E. C., Preliminary note on the geology of the Queensland coast with references t geography of the Queensland and N. S. Wales Plateau, Proc. Linn. Soc. New South Wales, pt. 2, pp 185, 1902.

[5] Gardiner, J. Stanley, The formations of the Maldives, Geographical Journal, pp. 277–296, March, Fauna and geography of the Maldive and Laccadive Archipelagoes, pp. 182, 183, 1901–3.

9. Hedley and Griffith Taylor[1] accepted Andrews's interpretations
d clearly showed that coral reefs of either atoll or linear form that
se above shallow platforms owe their shapes to prevailing winds and
rrents. They say:

This explanation differs from that of Sir J. Murray, who considers the atoll form to
assumed by abundant growth of well-fed corals on the margin and the solution of
ad coral rock in the interior. But if solution be so destructive how can a reef form
all?[2]

10. According to Daly[3] the depths in the drowned valleys within
rrier reefs, in barrier-reef lagoons, and in atoll lagoons in the Pacific,
e closely accordant and he attributes this accordance to Recent rise
sea level subsequent to deglaciation, whereby the depth of water
the Tropics was increased some 33 to 38 fathoms, thus submerging
tecedent platforms of marine planation. That glaciation and
glaciation effect the development of living reefs did not originate
th Daly, but it is principally he who has elaborated the hypothesis.
e gives in his papers an account of the earlier suggestions.

11. Wood Jones[4] considered sedimentation the critical factor in
ral-reef theory, as corals grow only where there is comparatively
tle deposition of sediment. He accepts the conclusions of Hedley
d Griffith Taylor on the importance of winds and currents in shap-
g atolls, and especially attacks the hypothesis of "a deepening or
dening of the lagoon by a process of 'solution'."

Although the results of my own investigations will be elaborated
subsequent pages, the following summary statement may here be
ade: I have greatly multiplied the evidence in favor of Recent
bmergence in the coral-reef areas in the western Atlantic, the Gulf of
exico, and the Caribbean Sea, and have shown that the living off-
ore reefs in those areas formed either during or after submergence
d are growing on submerged basement platforms where conditions
e favorable for the life of reef-forming corals. The platforms are
ntinuous beyond the limits of the reefs and their existence is in no
se dependent upon the presence of reefs.

I have also shown that the great Florida Plateau has existed as a
ateau since at least late Eocene time; and that some of the West
dian platforms are about as old. As these plateaus existed previous
Pleistocene time they could not have been formed by marine plana-
on during Pleistocene glaciation. Whatever be the cause of shift
position of strand line, off-shore reefs form on shallow submarine
ts during or after rise in sea level, provided the rate of movement
not too rapid. This explanation applies to the fossil reefs of

[1] Hedley, C., and Taylor, T. Griffith, Coral reefs of the Great Barrier, Queensland, Australasian Assoc.
v. Sci., Adelaide Meeting, pp. 397–413, 1907.
[2] Idem., p. 407.
[3] Daly, R. A., Pleistocene glaciation and the coral-reef problem, Amer. Journ. Sci., ser. 4, vol. 30, pp.
308, 1910; The Glacial-control theory of coral reefs, Amer. Acad. Arts and Sci., vol. 51, pp. 157–248, 1915.
[4] Jones, F. Wood, Corals and Atolls, London, 1910.

Florida and the West Indies as well as to the reefs living to-da
I have pointed out that there are in the Virgin and northern Leewa
Islands and off the shores of Central America certain submari
terrace flats, one at a depth of about 17 to 20 fathoms, another at
depth of about 26 to 30 fathoms, the deeper flat being separated fro
the shallower by an escarpment. These relations accord with t
demands of the Glacial-control theory as expounded by Daly.

Tests of Coral-reef Hypotheses.

The tests of the theories comprise ascertaining the answers to t
following questions:

1. Were the important coral reefs of the world formed during
after the submergence of their basements, either by a sinking of t
land or by a rise of ocean level due to some world-wide cause?

2. What is the rôle of corals as constructional geologic agent
What percentage of the sediments around coral reefs is composed
corals, and is the flat area between a barrier reef and the shore d
to infilling behind the reef or was there a shallow marginal flat befo
the reef formed?

3. Can a lagoon channel behind a barrier reef or the lagoon with
an atoll rim be formed by submarine solution by sea water or
submarine scour?

4. What and how much effect have wind-induced and other cu
rents in shaping coral reefs?

5. What effect have glaciation and deglaciation had on t
development of living coral reefs?

Before considering the fossil and living coral reefs of the W
Indies in their bearing on the answers to these questions, some f
the more important criteria to be used in answering the questio
will be briefly outlined.

Criteria for Recognizing Shift in the Position of Strand Line.

The criteria for recognizing elevation of a former strand l
comprise: (*a*) Coastal terraces bordered inland by escarpments
cliffs that may be inferred to owe their origin to wave cuttin
(*b*) wave-cut grooves in cliffs and sea caves that stand too high
have been formed at present sea level; (*c*) elevated beaches or ba
which under proper conditions form on shallow marine terraces a
at the mouths of embayments; (*d*) the presence above sea level
organisms that must have lived in the ocean.

The criteria for recognizing submergence of former strand li
comprise: (*a*) Indentation of the coast line caused by the sea inva
ing the lower parts of subaerially eroded valleys, the channels
which in many instances are preserved below sea level across a
beyond the existing strand line; (*b*) the presence below sea level

marine flats separated by relatively steep slopes or escarpments, that due either to marginal wave cutting by the sea or are due to the mation of a subaqueous profile above a previous profile;[1] (*c*) the sence, especially in limestones, below sea level, of solution wells, s, and caverns that inferentially were formed subaerially by the vent action of fresh water; (*d*) the presence inland of free openings t connect with the sea, showing that there are underground nnels by which ground water formerly flowed to the sea; (*e*) the sence of submerged peat bogs or swamp deposits composed of nts that grow only at or above sea level; (*f*) the presence below level of indurated limestone, the induration of which is due to ition of some of the original material and subsequent redeposi-n;[2] (*g*) erosion unconformities at the bases of marine formations, wing that there was subaerial erosion of the basement previous the submergence during which the formation was deposited or mulated in the sea.

The foregoing statements might be elaborated, but to do so seems necessary. The criteria enumerated are those I have actually sed in my own work.

Besides ascertaining the proper succession of changes in the posi-n of strand line, it is essential that the amount of the oscillations measured, that differential crustal movements be noted and dated, that an estimate be made of the endurance of the strand line in relation to present sea level.

CRITERIA FOR MEASURING THE AMOUNT OF VERTICAL SHIFT IN STRAND LINE, AND FOR DETERMINING THE RELATIVE AGES OF TERRACES AND THE PHYSIOGRAPHIC STAGE ATTAINED BY A SHORE LINE.

The criteria for estimating the exact amount of rise or fall of sea level are not yet definite, because adequate study has not been made of the factors that determine effective wave base and of the depth to which effective wave cutting extends. Notwithstanding this inadequacy of precise information, an approximation of the amount of change may be made. In the case of elevation, the base of a wave-cut escarpment or cliff, the flats of marine terraces, and wave-cut caves on sea cliffs, may be assumed to represent approximately former sea level. Approximate measures of the amount of subsidence may be based upon the depth of drowned valleys, the depth below sea level of the bottoms of submerged solution wells and

[1] For discussions of this subject see as follows:
Bell, Joseph, Factors in movement of the strand line, Washington Acad. Sci. Journ., vol. 12, pp. 413–20, 15; Factors in movements of the strand line and their results in the Pleistocene and Post-Pleistocene, Amer. Journ. Sci., ser. 4, vol. 40, pp. 1–22, 1915.
Vaughan, T. W., Some littoral and sublittoral physiographic features of the Virgin and northern Lee-ward islands and their bearing on the coral reef problem, Washington Acad. Sci. Journ., vol. 6, pp. 3–6, 1916.

[2] The fundamental principle of this criterion is discussed on p. 250, under the caption "Solubility of calcium carbonate in sea water."

caverns, and the depth to which peat or swamp deposits that we formed at or above sea level are submerged. Where there are reco nizable submerged wave-cut scarps, the depth of the base of t scarp below sea level is nearly a measure of the amount of su mergence; the depth in the West Indies in some instances probab exceeds the amount of submergence by about 6 fathoms. In t case of islands that rise from a common platform and which biolo and other data show were once parts of one land mass, the depth water o the common platform may be assumed to be an appro mate measure of the amount of the rise of sea level with reference those islands.

The criteria for determining the relative ages of elevated terra with reference to each other and for determining the amount deformation to which they have been subjected are as follows: Relative height; (*b*) relative amount of dissection; (*c*) relative deg of inclination and direction of the slope of the terrace flats; (*d*) pr ence or absence of a succession of higher and lower terrace flats promontory tips and in places protected from vigorous marine c ting; (*e*) stratigraphic relations of terrace deposits.

Estimates of the endurance of the present relation of sea le to strand line are based upon recognizing the stage of physiograp development of the shore line. Among the important features be observed are the presence or absence and the character of cliffs bordering the shore; the amount of delta and alluvial pl building at the mouths of stream ways; the character of beaches, b and spits; the nature and extent of the alluvial deposits back fr the shore; the profiles of valley sides; and the axial profiles of streams.

CRITERIA FOR ASCERTAINING THE RÔLE OF CORALS AS CONSTRUCTIO AGENTS.

The failure correctly to evaluate corals as geologic agents has b a defect of nearly all investigations of the so-called coral-reef pr lem; in fact, usually no attempt has been made to make such evaluation. This evaluation may be made in several ways, wh are as follows: (*a*) In studying fossil reefs exposed to view, t relative proportion of coral to other constituents of the rock sh be estimated; (*b*) in studying marine bottom samples, percent estimates of the proportion of the different ingredients should made; (*c*) for submerged platforms on which reefs grow, the of the reefs should be compared with the total area of the platf an effort should be made to ascertain the nature of the rock un lying the sea floor between the reef and the shore, and the contin in outline of the platform should be compared with the extent position of the reefs; (*d*) knowledge of the growth rate of co

n the relative frequency of specimens is known, permits an nate of the rate of their constructional work.

his subject as a part of the problem of the formation of coral reefs esses an importance that can scarcely be overestimated, for it prises critical tests of both the Darwinian and the glacial-control otheses. The topics in the foregoing list will be discussed *seriatim*.

) Estimate of the relative quantity of coral to other constituents nerged formations containing reefs, if they have not been exten- y recrystallized, is relatively simple, although great precision in ntitative expression is not to be expected. This topic will be ner considered in discussing the Caribbean, Floridian, and Baha- fossil reefs.

) Percentage estimates of material according to source are ult, but the results are of great value. The technique of making estimates is described in a memoir recently published by the egie Institution of Washington.[1]

Here it should be emphasized that one of the postulates of the vinian hypothesis is that the prism of material included between surfaces, namely, (1) the sea-bottom landward of the barrier,) surface assumed as an extension of the land slope under sea until ersects (3) a surface projected downward from the landward of the reef, is due to the presence of the reef (see figure 4, page Proof that a barrier has formed during or after submergence not carry with it proof that the prism of material above indi- is due to the presence of the reef.

ere are at least three criteria that can be applied in deciding ner or no the flat between the reef and the shore exists inde- ently of the reef. They are as follows: (1) If the flat is de- ent on the presence of the reef, where there are breaks in the r tongues of deep water should extend landward across the w bottom of the flat behind the reef; and where there is no reef should be either a normal profile of equilibrium or an approach h a profile, showing a deeper flat than that behind the reef, be- of the absence of an off-shore wall behind which sediment accumulate; but if the flat is independent of the reef, in general uld be continuous irrespective of the presence of the reef and in places extend beyond the reef limits. (2) If the formation flat is dependent on the presence of the reef, the reef should on the seaward edge of the flat, that is, the flat should not project rd beyond the reef. (3) It is often possible to discover the e of the rock forming the sea floor between a barrier and the

[1] Wa an, T. W., in collaboration with Cushman, J. A., Goldman, M. I., Howe, M. A., and others, ne al-water bottom samples from Murray Island, Australia, and comparisons of them with samples n F ida and the Bahamas, Carnegie Inst. Washington Pub. 213, pp. 235–297, pls. 94–98, 1918. See eci the article by M. I. Goldman, Composition of two Murray Island samples according to source of eri pp. 249–262.

shore. Such a floor if formed by agencies associated with the pr
ence of the reef will not be composed of rock demonstrably ol
than the reef, and will not exhibit geologic phenomena that in
clearly antedate the reef; but if it can be shown that the rock of
floor is older than the reef and that the floor has had a geologic
tory antecedent to the formation of the reef, it is demonstrated t
the reef is merely growing on the surface of a flat whose format
is entirely independent of the reef development.

(*d*) The growth rate of corals, which furnishes one of the che
to be applied to the Glacial-control hypothesis of the formatio
living reefs, is further considered on pages 253, 254.

SOLUBILITY OF CALCIUM CARBONATE IN SEA WATER.

As the formation of lagoon channels behind barrier reefs and
atoll lagoons by the solvent action of carbon dioxide (CO_2) dissol
in sea water is a part of the coral-reef hypotheses of Semper, Mur
A. Aggassiz, and Gardiner, if lagoons and lagoon channels have b
formed in the way indicated, in the Tropics the surface water
the ocean should contain an excess of carbon dioxide (CO_2)
should exercise a demonstrable solvent effect on calcium carbo
($CaCO_3$). If it should be found that there is no excess of ca
dioxide (CO_2) in such water and that the water is saturated
reference to calcium carbonate ($CaCO_3$), the hypothesis of the fo
tion of lagoons and lagoon channels in the manner postulate
Murray and others must be definitely abandoned.

In 1913, Mr. R. B. Dole undertook at Tortugas, Florida, ce
examinations that were intended to solve this problem, if poss
In 1914 I summarized in the following words the results I had
tained from a study of the bottom samples along the Florida
tract, those of Drew on dentrifying bacteria, and those of Do
the chemistry of the waters.[1]

There are two rival hypotheses for the formation of atolls: One of these attri
them to the submarine solution of the interior of a mass of limestone, the oth
counts for them by constructional agencies. In order thoroughly to test the so
hypothesis the results of four lines of investigation were brought to bear up
and all are accordant. (1) All the bays, sounds, and lagoons within the Florid
and key region are filling with sediment; (2) Drew's investigations of dentr
bacteria show that chemical precipitation of calcium carbonate is taking pl
the lagoons; (3) the chemical examination by R. B. Dole of samples of sea
flowing into and out of Tortugas lagoon, collected twice daily for a lunar period
that although both carbonate and bicarbonate radicles are in solution uncom
carbon dioxide is not present, and that the water possesses no capacity for
solution of calcium carbonate by virtue of its content of free carbon dioxide;
determinations by Dole of the salinity of the water within the Tortugas lagoo
at the southern end of Biscayne Bay show a higher concentration than that
open sea water on the outside, indicating that tidal inflow and outflow are no
cient completely to mix the water in the lagoons with the water of the surro

[1] Wash. Acad. Sci. Journ., vol. 4, pp. 27–28, Jan. 19, 1914.

and that concentration by evaporation is taking place. As the results of these s of inquiry are so positive, the formation of lagoons by submarine solution may definitely eliminated from consideration.

Since the publication of this statement other investigators have de important contributions to this subject, noteworthy among om are John Johnston, H. E. Merwin, and E. D. Williamson, of Geophysical Laboratory of the Carnegie Institution of Wash-ton, and Roger C. Wells, of the United States Geological Survey. lls says:[1]

n other words, sea water [from the Florida reef] appears to contain so much car-ate that in contact with the atmosphere at 1° C. it neither has nor acquires an reciable solvent action on calcite.

s I have considered the subject in detail in my paper on the rray Island bottom-samples[2] and in a paper on "Chemical and anic deposits of the sea"[3] I will merely say that sea water in al-water areas within the Tropics can not dissolve calcium car-ate, and that lagoon channels and atoll lagoons are not formed solution, but are flattish areas more or less completely inclosed by lt-up walls.

s lagoons are areas of sedimentation and not of removal of terial, their formation by submarine scour may also be discarded.

ECTS OF WIND-INDUCED AND OTHER CURRENTS IN SHAPING CORAL REEFS.

his is an old topic; in fact, considerable bibliographic work ld be needed to ascertain the names of all the investigators who e contributed to it and who deserve mention. That Darwin at t had an adumbration of the importance of these agents is indi-ed by his statement regarding Keeling atoll:[4]

at they [the waves] beat against it in the same peculiar manner in which the swell windward now obliquely curls round the margin of the reef, was evident from the lomerate having been worn in to a point projecting from the beach in a similarly que manner.

mong recent investigators Hedley and Griffith Taylor, as noted page 245, Wood Jones,[5] and I, in a number of my papers, two which are cited below,[6] have devoted attention to this subject. D ing the field season of 1914 I had numbers of Ekman meter rent-measurements made around Tortugas and at other places lg the Florida reef tract. The measurements to a certain degree

[1] ells, R. C., The solubility of calcite in sea water in contact with the atmosphere, and its variation ri temperature, Carnegie Inst. Washington Pub. 213, pp. 316–318, 1918.
[2] rnegie Inst. Washington Pub. 213, pp. 265–268, 1917.
[3] ol. Soc. Amer. Bull., vol. 28, pp. 933–944, 1918.
[4] ructure and distribution of coral reefs, ed. 3, p. 22, 1889.
[5] ral and atolls, pp. 253–261, 1910.
[6] e building of the Marquesas and Tortugas atolls and a sketch of the geologic history of the Florida reef ra Carnegie Inst. Washington Pub. 182, pp. 55–67, 1914; Sketch of geologic history of the Florida coral-ee ract and comparisons with other coral-reef areas, Washington Acad. Sci. Journ., vol. 4, pp. 26–34, 91

give quantatively the relations of currents to land forms, and co pletely confirm the more qualitative generalizations of Hedley a Griffith Taylor, which in brief are the axis of elongation of linear re is parallel to the direction of the dominant current while the bow a crescentic reef is directed toward the direction whence the domin current comes. These relations of reef form to current direction most striking where the reefs rise above comparatively shallow pl forms, as along the Great Barrier reef of Australia and along Florida Keys. In atolls that more or less encircle the flat tops submarine peaks, although currents are undeniably important shaping sections of the reefs, they are not of so great importance reefs that rise above shallow, long, wide platforms.

CRITERIA FOR DETERMINING THE EFFECT OF GLACIATION AND DEGLACIAT ON THE DEVELOPMENT OF LIVING REEFS.

Daly's elaborate paper on the Glacial-control theory of coral r has been cited on page 245. If the Glacial-control theory is true following conditions should prevail: (*a*) There should be evidenc geologically Recent submergence of most of the shore-lines of earth; (*b*) the average amount of submergence should be equal to amount of lowering of the ocean-level during Pleistocene glaciat (*c*) the position of the strand line during Pleistocene glaciation sho be indicated by scarps separating flats, and the amount of s mergence indicated by their present position below sea level sho agree with the amount of raising ocean level due to deglaciat (*d*) rate of growth corals should be such that since the disappeara of the continental ice sheets coral reefs could grow to a thick equal to the amount sea level was raised as a result of the deglaciat (*e*) living barrier coral reefs and atoll reefs should be superpose antecedent basement flats or platforms. It should here be st that the fact that there has been local differential crustal movem does not at all invalidate the importance of the Glacial-control the in its application to the explanation of the modern coral-reef deve ment.

Of the criteria stated in the foregoing list only the amoun vertical change in the position of sea level because of glaciation d deglaciation, the length of time since the disappearance of the g continental glaciers, and the rate of growth of corals need discus at this place. After their consideration some attention will be g to other criteria of less determined value.

AMOUNT OF VERTICAL DISPLACEMENT OF STRAND LINE BY GLACIATION AND DEGLACIATION.

It is entirely obvious that the withdrawal of water from the oc to form the Pleistocene continental glaciers would lower sea l and that the return of the waters so locked up to the ocean upon melting of the continental glaciers would raise sea level back to w re

it stood previous to the formation of the continental glaciers, unless c stal changes in the earth counterbalanced the effects of such with- dwal and return of oceanic water. Reference here will be made t only the two latest computations.

W. J. Humphreys, as part of a symposium before the Geological Siety of Washington, on March 24, 1915, said:[1]

The fact that the average thickness of the ice cap during the last glaciation can be so roughly estimated renders any calculation of its effect on ocean level correspondingly doubtful. It does not seem probable, however, that they should have averaged much if any thicker than the present caps of Greenland and of Antarctica, which a number of good observers have estimated to be about 1,000 meters. Taking this value and assuming the deglaciated area to be equal to one-fifteenth the area of the ocean, or, roughly, twice the glaciated area of North America, we estimate the change in sea level to have been about 67 meters. As already stated, this is only an estimated change, but perhaps it is a conservative estimate.

Daly in his paper on the Glacial-control theory of coral reefs summarizes his discussion in the following words:[2]

Combining results, it is seen that, at the time of maximum glaciation, the tropical sea probably had an average level which was 60 to 70 meters (33 to 38 fathoms) lower than at the present time.

The estimates of Humphreys and Daly are essentially the same. As maximum glaciation was probably not of long duration the greatest effect of submarine terracing would be expected in somewhat shallower depths, probably between 20 and 30 fathoms.

RATE OF GROWTH OF CORALS AND LENGTH OF POST-GLACIAL TIME.

Recently I have published two summaries of the results of my experiments and observations on the growth rate of Floridian and Bahamian corals, and compared my results with those obtained by investigators in the Pacific.[3] The following statements are taken from the second of the papers referred to in the footnote:

As has been stated, the primary object of this investigation was to get an approximate measure of the rate at which corals might build reefs. In order to make this estimate the true reef corals must be considered separately from those which live in other habitats. The reef species *par excellence* in the Recent and Pleistocene reefs of Florida and the West Indies is *Orbicella annularis;* after it in importance are *Maeandra trigosa*, *M. labyrinthiformis*, and *Siderastrea siderea*. Other corals, the most important of which is *Porites astreoides*, with *Agaricia* and *Favia fragum* of secondary importance, occur in the areas intermediate between the prominent heads. In some areas *Acropora palmata* is the dominant species. The massive heads form the strong framework of the reef, with infilling by other corals and other organisms. Therefore the upward growth rate of *Orbicella annularis* on the reef is critical. * * *

[1] Humphreys, W. J., Changes of sea level due to changes of ocean volume, Washington Acad. Sci. Journ., vol. 5, pp. 445–446, June 19, 1915.

[2] Amer. Acad. Arts and Sci. Proc., vol. 51, p. 174.

[3] Vaughan, T. W., Geologic significance of the growth-rate of the Floridian and Bahaman shoal-water coral: Washington Acad. Sci. Journ., vol. 5, pp. 591–600, 1915; Growth rate of the Floridian and Bahaman shoal-water corals, in On Recent Madreporaria of Florida, the Bahamas, and the West Indies, etc., Carnegie Inst. Washington Yearbook No. 14, pp. 221–231, 1916.

Using these figures [in the paper referred to] as the basis of a further computat a reef by the continuous upward growth of corals [*Orbicella annularis*] might at at a rate of 6 mm. a year a thickness of 25 fathoms=150 feet in 7,620 years; and rate of 7 mm. a year it might attain the same thickness in 6,531 years.

Should the growth rate of *Acropora palmata* be taken as a measure, the tim accumulate such a thickness would be considerably less. This species forms spr ing, palmate fronds, rising from stout bases. As age advances the fronds thicken can withstand the pounding of surf and breakers. The average upward growt between 25 and 40 mm. per year, but as the interspaces between the fronds are siderable in volume, comparisons with *Orbicella annularis* must be based upon rela increases in weight for a known period. * * *

These two estimates [as shown in the paper cited] give a measure of the limi reef formation under continuously favorable conditions for upward growth. S corals as *Orbicella annularis* might form a reef 150 feet thick in between 6,500 y and 7,600 years; while such corals as *Acropora palmata* might form a similar thick in 1,800 years.

* * * * * * *

The data available for the Pacific corals are not so abundant as those for the Atla nor have the records, with few exceptions, the same degree of precision. Howe they are sufficient for some general comparisons. The general growth rate of branc corals is nearly the same for both regions; but the growth of the massive forms in Pacific appears to be appreciably more rapid than that of similar forms in the A tic. Therefore it seems probable that in the coral reef regions of the Pacific and In oceans a reef 150 feet thick may form under favorable conditions in less than years. According to Gardiner such a reef might form in 1,000 years.

As the disappearance of the last continental ice sheets is estimated to have between 10,000 years ago in Scandinavia and Alaska and 40,000 years ago at Nia the data presented show that there has been ample time for the development of known living reef since deglaciation.

EFFECT OF LOWERING OF MARINE TEMPERATURE ON REEF CORALS DURING GLACIATION.

Daly in his paper on the Glacial-control theory devotes much at tion to the probable extinction of reef corals over large areas their restriction to only the hotter parts of the ocean during gla tion.[1] Daly's discussion of this subject is interesting and suggest but not really convincing. It is one on which far more researc needed. I rather hope that the data I have recently presente my paper on the temperature of the Florida coral-reef tract[2] will in furnishing a basis for such a computation. That there w lowering of the vitality of corals over large areas marginal to tro can scarcely be doubted, but that reef corals thrived throug Pleistocene time appears more than merely probable.

In this connection this following list of corals from the elevated r of Barbados is pertinent. Professor Jukes-Browne sent the collec to me after Prof. J.W. Gregory had published his paper on the badian elevated-reef corals,[3] making the statement that great had been taken in determining the height above sea level at w

[1] Amer. Acad. Arts and Sci. Proc., vol. 51, pp. 166–171.

[2] Carnegie Inst. Washington Pub. 213, pp. 319–339, 1918.

[3] Gregory, J. W., Contributions to the paleontology and physical geography of the West Indies, Soc. London Journ., vol. 51, pp. 255–310, pl. 11, 1895.

ch lot was obtained. The collection is now the property of the nited States National Museum.

rals from the elevated reefs of Barbados submitted by Prof. A. J. Jukes-Browne.

Elevation 1,043 feet. Horse Hill, St. Joseph.
Orbicella annularis (Ellis and Solander).
Elevation 845 feet. Cutting side of road, Parris Hill, St. Joseph.
Orbicella annularis (Ellis and Solander).
Elevation 747 feet. Cutting side of road, Market Hill, St. George.
Orbicella annularis (Ellis and Solander).
Elevation 720 feet. Russia Gully, St. Thomas.
Orbicella annularis (Ellis and Solander).
Maeandra labyrinthiformis (Linnaeus).
Elevation 707 feet. Haynesfield, St. John.
Stephanocoenia intersepta (Esper)
Orbicella annularis (Ellis and Solander).
Manicina gyrosa (Ellis and Solander).
Elevation 700 feet. St. Johns Church, St. John.
Maeandra strigosa (Dana).
Elevation 480 feet. Locust Hall, St. George.
Stephanocoenia intersepta (Esper).
Orbicella annularis (Ellis and Solander).
cavernosa (Linnaeus).
Siderastrea siderea (Ellis and Solander).
Elevation 362 feet. Ridge, Christ Church.
Siderastrea siderea (Ellis and Solander).
Elevation 360 feet. Small Ridge, Christ Church.
Orbicella annularis (Ellis and Solander).
Elevation 300 feet. Skeens Hill, near Lower Greys, Christ Church.
Orbicella annularis (Ellis and Solander).
Siderastrea siderea (Ellis and Solander).
Elevation 300 feet. Dayrells Hill, St. Michael.
Manicina gyrosa (Ellis and Solander).
Elevation 180 feet. Codrington Quarry, St. Michael.
Orbicella annularis (Ellis and Solander).
Manicina gyrosa (Ellis and Solander).
Elevation 160 feet. Cutting side of road, Charles Rose gully, St. orge.
Maeandra labyrinthiformis (Linnaeus).
Elevation 100 feet. Chelston Quarry, St. Michael.
Meandrina maeandrites (Linnaeus).
Manicina gyrosa (Ellis and Solander).
Siderastrea siderea (Ellis and Solander).
Acropora muricata (Linnaeus).

Elevation 80 feet. Prospect, St. James.
Stephanocoenia intersepta (Esper).
Orbicella annularis (Ellis and Solander).
Maeandra labyrinthiformis (Linnaeus).
Acropora muricata (Linnaeus) s. s. (as pebbles).
Elevation 70 feet. Grazettes, St. Michael.
Stephanocoenia intersepta (Esper).
Orbicella annularis (Ellis and Solander).
Maeandra labyrinthiformis (Linnaeus).
Siderastrea siderea (Ellis and Solander).
Elevation 40 feet. Sandy Lane, St. James.
Orbicella annularis (Ellis and Solander).
Maeandra labyrinthiformis (Linnaeus).
Elevation 40 feet. Colleton, St. Lucy Parish.
Maeandra strigosa (Dana).
Elevation 20 feet. Black Rock.
Acropora muricata (Linnaeus) s. s.

Just how much of Pleistocene time is represented by this collect
I can not say, but it is certainly a considerable part of it.

Mr. O. E. Meinzer, in the vicinity of Guantanamo Bay, Cuba,
tained living species of reef corals on Pleistocene terraces between
and 500 feet, at 275 feet, 200 feet, 125 feet, and 50 feet above sea le

It is unfortunate that Daly should have attempted to account
the disappearance in the West Indies of so large a percentage of gen
that now persist in the Indo-Pacific by appeal to the lowering of
temperature in the western Atlantic Ocean through Pleistocene gl
ation. In a recently published paper[1], as well as the present one
have shown that the genera had disappeared previous to Pliocene ti

It is at present my opinion that not enough is known regarding
effect of lowering of marine temperature during glaciation to se
as a basis for very strong arguments for or against the validity of
Glacial-control hypothesis.

VALLEY-IN-VALLEY ARRANGEMENT AND CLIFFED SPURS.

Professor Davis says in his Shaler Memorial study of coral reefs:

Furthermore, if the embayments of a central island within a barrier reef result f
the drowning of valleys that were eroded with respect to lowered sea level of a relati
short glacial period, then each valley must be entrenched in the floor of a pregla
valley; and above the head of each embayment resulting from the drowning
new-cut valley, there should be a "valley-in-valley" landscape, unless the
glacial valley was so young and narrow that its sides were undercut and destroyed
the deepening and widening of the glacial valley.[2]

[1] Vaughan, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, California, and its signific
U. S. Geol. Surv. Prof. Pap. 98-T, p. 366, 1917.
[2] Amer. Journ. Sci., ser. 4, vol. 35, p. 240, 1915

The character of the entrenching within an established valley after wering of sea level will depend upon the off shore slope of the sea ottom previous to the lowering of sea level. As any acceleration headward erosion by a stream depends upon increase in steepness the longitudinal profile of the stream bed, unless the gradient of e lower course of the stream is considerably increased there will no visible valley-in-valley landscape after submergence following glaciation. Subsequently I will show that in the West Indies there abundant evidence of another kind that during Pleistocene time a level was lowered, and that at the close of Pleistocene time it was ised. Valley-in-valley arangement is a criterion of very doubtful lue.

Professor Davis also insists that if the Glacial-control hypothesis correct, the spurs of islands within barrier reefs should be cliffed—e cliffs cut during Pleistocene glaciation. As promulgated in print Professor Davis, I doubt the validity of this criterion. Perhaps e following hypothetical explanation may apply in some instances: Around volcanic islands, the centers of which are far enough from e shore for the surface profile of the ejecta to have assumed the eoretic catenary curve, marine planation may proceed without at st cutting pronounced cliffs. If the material on the higher slopes not greatly consolidated, alluviation and surface creep may deliver tritus more rapidly than the sea can remove it by marginal cutting d by undertow and other transporting agents. The sea may thus held back from the interiorly situated harder volcanic rocks and e development of well-marked sea cliffs may thereby be prevented ile the sea bottom would be aggraded near shore and a submarine t produced. Should sea level then fall so that the shore line would ift to the outer edge of the previously formed flat, erosional processes ght obliterate the low scarp carved into unconsolidated colluvial d alluvial material. Under such circumstances, should the sea-ttom gradient be less than that of the stream profiles, the lowering sea level would not lead to the development of valleys-within-lleys, and alluvial plains might be pushed forward beyond the ends the interstream spurs. Should sea level rise back to its former and reef corals might establish themselves on the submerged flat any place where the proper ecologic conditions might be found d develop into a barrier reef, off a land area on which there would no valley-in-valley arrangement of stream courses and along whose ores there would be no cliffed spurs. This is an hypothetical in-nce, but that it is possible is apparently shown by the island of . Christopher, West Indies, where such an arrangement of central lcanic mountains and relatively flat areas underlain by volcanic cta and colluvial and alluvial material intervene between them

and the shore. In other volcanic islands the sea may not be h back from the harder rocks and may cliff them.

There are numbers of possibilities which deserve consideration, l the actual explanation of how present conditions were brought ab is possible only through detailed field work in each area.

Some other kinds of shore lines may be mentioned. It is v known that one of the important factors in determining the amo of cliffing and the character of the cliffing of some shores is geolc structure. In an uplifted island composed of bedded sedime which have been moderately tilted the highest cliffs will be on up-dip side along the line of the strike; the cliffs will decrease height from the up-dip exposure along the line of the dip, and on side of the island where the rocks pass beneath sea level there may almost no cliffs. These relations are well illustrated in Anguilla other islands in the West Indies. After such an earth block been outlined there may be oscillation of strand line without furt local crustal deformation.

The island of St. Croix is interesting in this connection. J south of its north shore, which is determined by a fault, are matur dissected mountains which attain an altitude of about 1,000 f Off the south foot of the highland is a sloping, slightly undulat plain, underlain by limestone, which extends to the south co (See pl. 70, fig. D). If this island were submerged 120 feet the li stone plain would form a submarine flat from one to about th sea-miles wide. Corals might grow on such a flat and form a bar reef inside which there would be no strongly cliffed spurs along shore, while the mountains would be in a stage of mature dissecti

American Tertiary and Pleistocene Reef Corals and Coral Reefs.

Most investigators of the genesis of coral reefs have conside only the modern; but the ancient, or fossil, reefs in many instan afford better opportunities than the living reefs to determine geologic character of the basement on which the reefs have b built, the change in the relation between the reef basement and level, and the importance of corals as constructional agents. southeastern United States and near-by West Indian Islands furn numerous examples of both ancient and modern coral reefs, these have been the subject of investigation for many years. location of the Tertiary fossil reefs in the southeastern United Sta their associated faunas, the inclosing sediments, including in m instances both the overlying and underlying strata, the stratigra relations of the successive geologic formations, the geologic struct and the geologic history, have been ascertained with a fair de of accuracy. The coralliferous beds range in age from the base of Eocene to Recent, and the coral fauna of each geologic formatio

own with approximate completeness. The total coral faunas have lded some hundreds of species.

EOCENE REEF CORALS OF ST. BARTHOLOMEW.

The corals obtained from the St. Bartholomew limestone are listed page 194. Although there are many specimens and species of reef ies, they scarcely form a reef properly speaking. However, the atigraphic relations are interesting. The best collecting ground on the northeast face of the northwestward projecting limb of the and, between Anse Lézard at the northwest and Jean Bay at the itheast. Anse Écaille lies between the two bays mentioned. eve's [1] account of the geologic succession is correct, perhaps with ne modification of his dates of a part of the igneous rocks. The se of the section is composed of volcanic agglomerate, above ich there is interbedded agglomerate or sandstone, conglomerate mposed of volcanic material, and limestone, succeeded by mas- e, hard, blue limestone. Most of the corals occur in the lower rt of the sedimentary formation, in the limestone or in the ter, more rapidly weathering layers of calcareous sandstone, in ich there is rehandled volcanic material. In conglomerate at e base of one exposure I observed boulders of volcanic material much as 8 inches in diameter. Although, as Cleve stated, there is me interbedding of the limestone and agglomerate in the lower part the sediments the upper formation rests unconformably on the lver.

The gradation upward into purer, more massive limestone has been ntioned. The presence in the higher limestone of a few corals of e same species as those in the lower beds and the abundance of lcareous algae in some places, indicate a shoal-water deposit; d, as the area of the deposit is relatively extensive, the evidence in favor of its having been laid down on a submerged flat.

The Jamaican Eocene corals are shoal-water forms but they are ally not of reef facies.

WEST INDIAN MIDDLE OLIGOCENE REEFS.

ANTIGUA.

That the bedded volcanic tuffs underlying most of the Central ain of Antigua dip under the Antigua formation toward the north- st is indicated by the general structure of the island, and is con- med by a well record, kindly furnished me by Dr. H. A. Tempany, vernment chemist of the Leeward Islands. The record mentioned of a well bored on Fitches Creek, half a mile northeast of the south- st boundary of the limestone. Compact, noncalcareous rock as struck below the limestone. In the Central Plain patches of

[1] Cleve, P. T., On the geology of the northeastern West India Islands. K. svenska Vet.-Akad. Handl. 9, No. 12, pp. 24-27, 1872.

gravel and cobbles overlie the surface of the bedded tuffs at a numb of places, two of which are Casada Gardens and Gunthorpe suga factory. At Morris Looby Hill, near the head of Willoughby Ba conglomerate immediately underlies the limestone; and the bas contact of the formation is also exposed on the north side of Wi loughby Bay, where it is underlain by conglomerate, mostly compos of basic volcanic material. The main reef occurs within the Antigu formation at or near its base and is exposed along a southwes northeast line from Willoughby Bay to near Wetherell Point. Th Antigua reef therefore grew upon a basement that had been su aerially eroded and was later depressed below sea level. The re and the limestone of which the reef forms a part were formed duri or after the submergence of their basement. Associated with th corals are many specimens of several species of *Lepidocyclina*, whic are organisms characteristic of shallow, tropical water. The are extent of these sediments, coupled with the fact that the deformatio of the water-bedded tuffs that lie below the Antigua formation is n much greater than that of the Antigua formation, indicates th they were deposited on a submarine flat. In the northeastern pa of the island both the tuffs and the limestone, according to J. W Spencer, dip northeastward at a rate of 12° to 20°.[1] My own mea urements show dips of about 20° toward the north or northeast f the volcanic tuffs and dips between 10° and 15° in amount, and ran ing from N. 60° E. to N. 70° E. in direction, for the Antigua formatio The rocks are more disturbed in the Central Plain, where the di of the volcanic tuffs were measured. Therefore, according to th available evidence the Antigua formation was a relatively extensi formation deposited in shoal water on a flattish floor.

The main reef-coral bed is about 60 feet thick and is near th bottom of the formation. Above it corals are scarcer, but appe to be too sparingly distributed throughout a thickness of about 3 feet of limestone above their profuse development nearer the bas or the Antigua formation seems to have a total thickness of a litt more than 350 feet.

PORTO RICO.

The middle Oligocene coral fauna, as has been stated on page 20 occurs in the geologic formation to which Hill applied the nam Pepino. This is a hard, calcareous marl, full of coral heads, wi occasional indurated strata of white porous limestone. It is w exposed north and northwest of Lares in the Pepino Hills, when the name for the formation is derived and where the collection corals submitted to me by Mr. Hill was obtained.[2] This is the fo

[1] Spencer, J. W., On the geological and physical development of Antigua, Geol. Soc. London Qua Journ., vol. 57, pp. 494, 496, 1901.

[2] Hill, R. T., Notes on the forest conditions of Porto Rico, U. S. Department of Agriculture, Div. Forestry Bull. No. 25, pp. 14, 15, 1899.

tion to which C. P. Berkey later applied the name Arecibo forma-
n.[1] I have no field acquaintance with the formation but from
ne notes on it made by Cleve, before it had been named, from the
criptions of Hill and Berkey, and from some of the corals collected
members of the New York Academy Porto Rican investigations,
m inclined to the opinion, that there is not a "formation" but a
up of formations of similar lithology, for the "formation" contains
h middle Oligocene (Antiguan) and upper Oligocene (Anguillan)
sils, and probably also some Miocene species. Ultimately the
rmation," as Berkey also has suggested, will probably be split
o several formations; it seems to me that there will be at least
ee and perhaps more. Only the stratigraphic relations of the base
he formation particularly need consideration here. These rela-
ns are those of unconformity according to Berkey, who says:[2]

bove it [the Arecibo formation] in all cases lie the recent alluvial deposits and the
Juan formation, and below it lie the older and more complicated igneous and
nentary rocks. The break between these two represents the chief unconformity
he whole geological column.

n excellent illustration of the unconformity below the "Arecibo"
iven on page 16, figure 3, of Berkey's paper.
Berkey says in his summary of the geologic history of the island:[3]

here more simple marine conditions came into control, as would happen when
nergence or planation had masked or destroyed the more elevated source of sup-
the deposits became almost wholly reef limestones and shell limestones, with
minor amounts of strictly detrital material irregularly distributed.

he middle Oligocene reef-coral development of Porto Rico, there-
, took place after its basement had been subaerially eroded and
n depressed below sea level, and it seems that the basement prior
ts submergence had been almost reduced to a peneplain surface.

CUBA.

eef corals of middle Oligocene age were first collected in Cuba,
Rio Canapu, by Arthur C. Spencer, who obtained three species,
f which also occur in Antigua; but the only at all extensive col-
ion is from the vicinity of Guantanamo, and was made by O. E.
nzer, who studied in detail the stratigraphic relations of the coral-
ous formation. I am taking the following note from a manu-
ot by Mr. Meinzer, now awaiting publication. That there is a
nounced unconformity is indicated by a conglomerate at the base
he formation. Previous to the submergence, during which the
l reefs were formed, there was a long period of subaerial erosion,
t geologic investigations have not been prosecuted over large

[1] rkey, C. P., Geological reconnaissance of Porto Rico, New York Acad. Sci. Ann., vol. 26, pp. 12-17,
1.
[2] m. p. 3.
[3] m. p. 59.

enough areas in Cuba to draw inferences as to the physiograph features of the land surface resulting from the erosional activitie

WEST INDIAN AND PANAMANIAN UPPER OLIGOCENE REEFS.

ANGUILLA.

Basic igneous rock above which in places there is some sandsto is exposed below the coralliferous limestone at Crocus Bay a Road Bay. The contact is very clearly one of erosion unconformit The following is a composite of the sections exposed at Crocus Ba

Geologic section at Crocus Bay, Anguilla.

3. Hard cavernous limestone, with few or no corals..... 60 fe
2. More or less argillaceous limestone with some beds of harder, purer limestone; contains fossil corals from bottom to top, some coral heads as much as 2 feet in diameter; this member subdivisible into subordinate beds about..... 200 fe
1. Yellowish and brownish clay underlain by dark blue-black clay, or sandstone and conglomerate of igneous material overlying basic igneous rock (exposed at Pelican Point)..... 5 feet

The exposure at Road Bay is essentially the same as that at Croc Bay.

The Anguillan reef was evidently formed during submergence af the subaerial erosion of its basement.

It should be emphasized that the richly coralliferous limestone overlain by more massive, harder, limestone in which there are f or no corals; and that the areal extent of the shoal-water limest indicates a submarine flat.

CANAL ZONE.

The Emperador limestone, according to Doctor MacDonald, l unconformably on several of the beds belonging to the underly Culebra formation, and supplies another instance of a fossil coral r with an unconformable basal contact.

The stratigraphic relations of the important West Indian and Ca Zone reef corals and coral reefs are summarized in the follow table:

Stratigraphic relations of West Indian and Canal Zone Eocene and Oligocene reef co and coral reefs.

Age.	Locality.	Basal contact.	Overlying rock.	Surface of b ment.
Upper Oligocene	Canal Zone (Emperador ls.)	Unconformable on Culebra formation.	.....	.....
	Anguilla	Unconformable on igneous rock or on sandstone and conglomerate.	Limestone without or with few corals.	Submerged
	Antigua	do	do	Do.
Middle Oligocene	Porto Rico (Pepino formation).	do	do	Do.
	Cuba (Guantanamo)	do	.....	Not known
Upper Eocene	St. Bartholomew	do	Limestone without or with few corals.	Submerged

ll of the fossil reefs discussed in the foregoing remarks were ned during periods of subsidence that followed subaerial erosion their basements. The basal contacts might be interpreted as porting Darwin's hypothesis, but in four of the six instances the s are buried under later nearly pure limestones in which there are or no corals. What caused the change in the character of the ments, and coincidently led to the extermination of the reefs is known; but the organisms in the overlying sediments indicate low, tropical waters, and as the geologic formations are areally nsive (relatively speaking), they were evidently formed on marine flats. The corals began to grow on such flats and were nately killed. So long as the ecologic conditions were favorable, corals flourished, but died when the conditions changed. The nation of the flats can scarcely be attributed to the corals.

WEST INDIAN MIOCENE REEF CORALS.

eager developments of reef corals during the Miocene occur in a and Santo Domingo, but at present no Miocene reefs are known ss the name reef be applied to the corals found in the La Cruz l, eastward from La Cruz to the intersection of the railroad with highway from Santiago to the Morro. The La Cruz marl is a led formation in which there are a few reef corals. The presence ebbles in the basal part of the formation at the south end of iago Harbor suggests an erosion unconformity with some older iary formation.

o Pliocene reef corals are at present known in the West Indies. erroneous suggestion, that a coralliferous limestone exposed in uarry on Calle Infanta, opposite Castillo de la Punta, Habana, nt be Pliocene, has been corrected on page 224. This limestone es to represent very nearly the same horizon in the Miocene e Bowden marl of Jamaica; it may be stratigraphically somewhat er. It contains some corals of reef facies but it can not appro-ely be called coral-reef rock. The stratigraphic relations of the of the deposit are not known.

WEST INDIAN PLEISTOCENE REEFS.

he West Indian Pleistocene reefs, whose stratigraphic relations been critically investigated and can be discussed here are those maica and Cuba. Mr. R. T. Hill has placed in my hands a uscript describing the Pleistocene reefs of Barbados, and Doctor Donald will discuss those of Costa Rica and Panama in his memoir e geology of the Canal Zone and adjacent areas.

he basal contacts of the Jamaican Pleistocene reefs, as has been rately presented by R. T. Hill in his account of the Jamaican [1]

[1] Hill, R. T., The geology and physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, pp. 90-99, 89.

reefs, at least usually show unconformable relations. Altho that Agassiz was aware of the unconformity at the base of the Cu Pleistocene reefs can be inferred from his descriptions, he did emphasize the stratigraphic relations; however, he does say regar the living Cuban reefs: "In Cuba they [the coral reefs] abut upor Tertiary limestone of its shores." I observed the unconform relations at Baracoa, and stated that "Upper Oligocene yello calcareous marls or limestone are found in the vicinity of Nuev also at *Baracoa, where they immediately underlie the Pleistocene co soborruco*."[1] On page 32 of the same report it is stated: "It sh be added here that all of the elevated Pleistocene coral reefs as by us and all of those recorded by those whom we consider co tent observers, are plastered on the surface of the upper Oligo [mostly Miocene] formations, or in some instances upon older g gic formations."

Unconformable relations between the elevated Pleistocene and the underlying Miocene limestone or marl are observab Matanzas, Habana, and Santiago. The rock in the left foregr (pl. 71, fig. A,) is the slightly elevated soborruco (coral-reef that extends into the mouth of Santiago Harbor, clearly s ing that the harbor was outlined as a drainage basin pre to the formation of the particular reef now under consider The bluff and slopes in the background and on the right side c illustration are formed in the Santa Cruz marl.

The known unconformable relation at the base of the Pleist elevated reefs was the basis of inferred "subsidence of 80 to 100 during the Pleistocene; this subsidence was followed by elevatio channeling in the mouth of the harbor; and this was follow Recent submergence.[2] I have recently prepared a revised accou the shore-line phenomena of Cuba, and present the following mary for the vicinity of Habana:

1. Stand of land high enough for the subaerial erosion basement of a reef that seems to be about 30 feet above sea at present, and for the outlining by erosion of Habana Harbo

2. Submergence in Pleistocene time to a stand about 30 feet than at present.

3. Emergence in Pleistocene time sufficient to permit the c of a channel, now submerged 100 feet in Habana Harbor; the a of this emergence would be about 100+ feet = 130 feet.

4. Submergence, assigned to Recent time, to a depth of 100 feet.

[1] Hayes, C. W., Vaughan, T. W., and Spencer, A. C., A geological reconnaissance of Cuba, m the direction of General Leonard Wood, Military Governor, p. 23. The upper Oligocene in this is now considered Miocene. The italicized part of the sentence is in Roman letters in the origin

[2] Idem., p. 34.

. There may have been minor oscillations, for instance the 5-foot orruco may represent slight elevation subsequent to the last mergence.

Ir. O. E. Meinzer, in his manuscript, "Geologic reconnaissance of egion adjacent to Guantanamo, Cuba," referred to on page 204, es the following summary of events for the vicinity of Guantanamo:

. (Previous to the formation of the terraces) "Erosion, resulting he excavation of the principal valleys now in existence, some of m probably below present sea level.

. Submergence sufficient in amount to bring the land at least feet below the level of the present shore line.

. Successive stages of emergence and perhaps slight tilting of the l, alternating with stages of quiescene, the emergence being about feet in amount so that the land area stood about 100 feet higher n at present, thereby permitting stream erosion below the present level; during the stages of quiescence sea benches and cliffs e formed at different, successive stands of the land.

Submergence to the present level, resulting in the drowning of lower parts of the stream valleys and in the production of innumble small estuaries, bays, and coves.

Filling of the submerged valleys and development of a new sea ch by destructive and constructive processes."

he reefs considered in this section are fringing reefs. They rest onformably upon their basements, but were formed during ses in emergence.

TIARY AND PLEISTOCENE REEF CORALS AND CORAL REEFS OF THE UNITED STATES.

SOUTHEASTERN UNITED STATES.

n the United States Tertiary reef corals first appear at the base he Eocene in the Midway group in Alabama, but these are not iciently abundant to entitle the deposit to the designation al reef."

ne oldest Tertiary coral reefs in this province are of middle ocene age, and have been studied at Salt Mountain, near Jackson, bama, and near Bainbridge, Georgia. The basal contact of the e at Salt Mountain is not exposed, and its nature is, therefore, nown. The reef in the basal part of the Chattahoochee formation ainbridge, Georgia, rests on the surface of the upper Eocene Ocala stone, which shows evidence of subaerial erosion, and is exposed o place to place along Flint River throughout a distance of 8 miles. It is relatively thin, perhaps only 10 to 15 feet thick, contains a fauna of about 30 species of corals, mingled with h are many specimens of *Lithothamnion* and large *Lepidocyclina*.

ne next younger development of reef corals is in the upper part ne Chattahoochee formation and its stratigraphic equivalent,

the "silex" bed and limestone of the Tampa formation. Corals sufficiently abundant to justify being designated "reefs" at sev localities, the most important of which are 18 miles south of Ta hassee, Florida, in several counties in southern Georgia, and Tampa, Florida. Coralliferous limestone of the same or nearly same age is exposed one-half mile south of River Junction, Flor and at old Jacksonboro, Georgia. Well borings in Tampa show beneath the coralliferous limestone is a variable thickness of which overlies the irregular surface of the Ocala limestone, indica subaerial erosion, followed by submergence. The coralliferous l are stratigraphically below the next younger set of deposits grou under the Alum Bluff formation, indicating the continuation of sidence after the formation of the reefs. The thickness of the and coralliferous beds is not great, perhaps between 10 and 20 The fauna comprises about 20 species of corals. Where not silic and its character may be studied, the limestone associated with corals is of complex origin. It is partly organic, probably in pa chemical precipitate, and contains terrigenous impurities. This cates that the reefs and corals of this period grow during subsid on a previously formed platform, but possess greater value for aid in stratigraphic correlation than as constructional agents.

The Alum Bluff formation, which, in my opinion, is of Mio age, according to the usage adopted by the United States Geolo Survey is subdivided into three members, which named from bottom upward are the Chipola marl, Oak Grove sand, and S River marl. The basal Chipola marl member was known on an area extending from Alum Bluff on Apalachicola River west to Chipola River until it was recently identified by Miss Julia C ner from a collection made by Dr. E. H. Sellards at Boynton Lan on Choctawhatchee River, in Washington County. The be Chipola River seems conformably to overlie the Chattahoochee fo tion, it is conformably overlain by higher beds of the typical Bluff formation, and is between 15 and 17 feet thick. Of the or five species of corals found at this horizon, one is of reef fac massive species of *Goniopora*. Subsidence was in progress these coralliferous beds were being deposited.

Before completing the discussion of the Alum Bluff formatio tain events antecedent to its deposition in central peninsular Fl should be stated. Previous to the deposition of Chattahooche Tampa sediments, the Ocala limestone was deformed with the duction of a low, elongate dome, the axis of which extends near Gainesville to near Ocala. On both the east coast an west coast along an east-west line through Gainesville the su

he Ocala is below sea level and is overlain by younger forma-
is, while along the axis of the dome its surface rises from 80 to
ttle more than 100 feet above sea level. This low dome formed
he upper Oligocene sea an island or a group of islands to which
ave applied the name "Orange Island." The Chattahoochee
Tampa formations were deposited on the western slope of this
nd but they are not known in central Florida. The subsidence
ch brought about the deposition of these two formations con-
ied until the Alum Bluff sea advanced entirely across central
rida, where deposits of Alum Bluff age rest on the surface of the
la limestone apparently without the intervention of deposits of
rmediate age.

he portion of the Alum Bluff formation above its basal member
ains in central Florida at numerous localities heads of corals of
facies belonging to the genus *Siderastrea*. At a place near
ger Sink, about 8 miles north of Alachua, Florida, there is a
rastrea reef, which, according to aneroid barometer measurement,
bout 35 feet thick. The sediments associated with the Alum
ff reef corals are greenish, usually phosphatic sands and clays, and
ure phosphatic, in places magnesian limestone. The corals are
dedly subordinate in importance to other constructional agents,
ough they grew on a subsiding basement.

lum Bluff sedimentation was succeeded by uplift and subaerial
ion preceding the depression initiating the deposition of the
ctawhatchee Miocene. Although the Miocene Choctawhatchee
Chesapeake faunas comprise about a dozen species of corals of
inctive facies, no reef corals are known as the temperature of the
er was evidently too low.

o Pliocene coral reefs are known, but corals of reef facies are well
esented in the Caloosahatchee marl, which is largely composed of
uscan shells. The stratigraphic relation of the Caloosahatchee
l to the Miocene has not been definitely ascertained, but available
ence suggests separation by an erosion unconformity. Whatever
relation may be, the formation was deposited during subsidence.
ls are of slight importance as contributors of material to the
ation, as Heilprin long ago pointed out.

he following table, which is a slightly revised copy of a table
iously published,[1] shows the stratigraphic distribution of coral
s and reef corals from Oligocene to Recent time, and their rela-
to changing sea level.

[1] ghan, T. W., and Shaw, E. W., Geologic investigations of the Florida coral reef tract, Carnegie
Washington Yearbook No. 14, p. 238, 1916.

Stratigraphic distribution of coral reefs and reef corals in the southeastern United S from Oligocene to Recent time, and their relation to changing sea level.

Series.	Geologic formations, members, unconformities.	Distribution of reef corals and coral reefs.	Change relation basemen sea lev
Recent		Coral reefs	Submerg
	Erosion unconformity.		
Pleistocene	Key Largo limestone	Coral reefs	Subsiden
	Erosion unconformity.		
Pliocene	Caloosahatchee marl	Reef corals	Subsiden
	Erosion unconformity.		
Miocene	Choctawhatchee marl	No reefs, a few corals	Subsiden
	Erosion unconformity.		
	Alum Bluff formation: Shoal River marl.	A few corals; slight development of reefs in central and northern peninsular Florida.	Subsiden
	Alum Bluff formation: Oak Grove sand		
	Alum Bluff formation: Chipola marl	A few corals; one species of reef facies.	
Oligocene	Chattahoochee formation: Upper	Coral reefs (Tampa, Fla., etc.)	Subsiden
	Chattahoochee formation: Lower	Coral reefs (Bainbridge, Ga.)	Subsiden
	Erosion unconformity.		
Eocene	Ocala limestone	No coral reefs	Subsiden

The table shows, besides the stratigraphic distribution of the r and reef corals, that, with possibly one exception, each developm occurred during subsidence which followed subaerial erosion.

To consider the basement of these fossil reefs: The geogra extent and composition of the limestones of upper Eocene age, w form the basement of the Floridian plateau, have been ascertai with considerable exactness. The surface outcrop has been map in Georgia and Florida, and well borings have revealed the pres of limestone of this age and character under younger formation west Florida, at Panama City, and in Peninsular Florida, at Tar Key West, Key Vaca, and Palm Beach. The limestone is lar composed of the remains of Foraminifera, including myriads o *Nummulites* and orbitoidal Foraminifera, Bryozoa, and some moll and echinoids, with which is an undetermined proportion of ch cally precipitated calcium carbonate and some terrigenous mate Corals are always rare and are usually absent. The organisms oc ring in the formation are characteristic of tropical, shoal wate fathoms or less in depth. As the 100-fathom curve delimits the b merged border of the Coastal Plain, it is evident that the Flori plateau was a part of the Coastal Plain and had essentially its pre outline back in upper Eocene time before the formation of the ol Chattahoochee reef, which was therefore superposed on a subsi platform not produced by corals. The paleogeographic develop of the Floridian plateau shows that each successive developme Tertiary reefs was on an antecedent platform which was forme agencies other than those dependent on the presence of coral r In all instances the volume of coral as compared with material other sources is of minor and usually of negligible importance.

he accompanying map (fig. 7) shows the location of the Oligocene
s with reference to the Plateau surface.

hat Pliocene deposition was followed by uplift, erosion, and de-
sion, is shown by the fact that the Pleistocene shell marls along
osahatchee River rest on the eroded surface of the Pliocene. The
stocene reefs, the location of which is shown on the map (fig. 8),
e formed during subsidence which followed uplift at the close of
cene deposition. At the base of the reef, which is 105 feet thick,

.—Florida, Ocala limestone plateau with superposed Oligocene and Miocene coral reefs
reef corals. *Oc. ls.*=Ocala limestone; the figures are for the depths of its upper surface
low sea level. *Ch*=Chattahoochee and Tampa Oligocene formations. *Al. B.*=Alum Bluff
cene formation.

is calcareous deposit, 55 feet thick, of undetermined age. Beneath
it re 450 feet of sand, mostly quartz, of Miocene age, below which
fo w in descending order, limestones of Chattahoochee and Ocala
ag. but without any development of reef-corals. Planimeter meas-
u ments indicate an area of 66 square miles for the Pleistocene reef
against an area of 1,670 for the chemically precipitated calcium car-
b ate of the Miami and Key West oolites. I have already published

the statement that in Pleistocene time the calcium carbonate ch
cally precipitated probably predominated over that secreted by c
in the ratio 100:1.[1]

The theory advanced by Louis Agassiz [2] for the building of pe
sular Florida is familiar to most geologists through the writing
LeConte. Agassiz says: * * * "the peninsula itself has
been a reef at least as far as the 28th degree of north latitude,
shown by the investigation of the Everglades, and by the examina

FIG. 8. FLORIDA, LOCATION OF PLEISTOCENE CORAL REEFS AS SHOWN BY +, AND THE LOCATION OF THE AGASSIZ–LECONTE BOUNDARY OF SUPPOSED CORAL FORMATION.

of the rocks at San Augustine." According to LeConte's map a
half of peninsular Florida was formed through the agency of
reefs.[3] (See figure 8, above.)

Eugene A. Smith, in 1881, showed that Eocene deposits ex
south of Ocala into the peninsula; Heilprin showed that coral
unimportant to the latitude of Lake Okechobee; Alexander Ag

[1] Vaughan, T. W., Sketch of the geologic history of the Florida coral-reef tract and comparison wit
coral-reef areas, Journ. Washington Acad. Sci., vol. 4, p. 26, 1914.

[2] U. S. Coast and Geodetic Survey Ann. Rept. 1851, pp. 145–160, 1852.

[3] Elements of geology, ed. 4, p. 163.

epted the results of Smith and Heilprin but contended that the thern end of the peninsula is composed of wind-blown coral sand. ter investigations have established that the material comprising is part of the peninsula is neither coral sand nor is it wind-blown. tecedent to the Recent reef out of an area of between 25,000 and 000 square miles, perhaps as much as, but probably less than, 66 are miles may now be attributed to coral.

The data on the fossil reefs of the Southeastern States may be marized as follows:

. Corals have played a subordinate part, usually a negligible part, the building of the Floridian plateau.

. Every conspicuous development of fossil coral reefs or reef als took place during subsidence.

. In every instance the coral reefs or reef corals have developed platform basements which owe their origin to geologic agencies er than those dependent on the presence of corals.

PLIOCENE REEF CORALS FROM CARRIZO CREEK, CALIFORNIA.

Vendenhall [1] has described in detail the relations of the coralli- ous beds at this locality, and I have republished his statements ny account of the collection of corals made by him and Dr. Stephen wers.[2] There is here another instance of a richly coralliferous mation with an erosion unconformity at its base.

IVING CORAL REEFS OF THE WEST INDIES, FLORIDA, AND CENTRAL AMERICA.

No general account of the position and general features of the ng reefs within the region above mentioned will be given here, as subject has been fairly well treated by Alexander Agassiz for the st Indies and Central America,[3] and during the past eight years ave published a number of papers, listed in the footnote,[4] on the

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e reef corals of southern Florida, Carnegie Inst. Washington Year Book No. 12 (for 1913), pp. 181–183,

[Footnote continued on page 272.]

Floridian, Bahamian, West Indian, and Central American re
In addition to my studies in the field and my work on charts a
maps in the office, I have compiled all available information
Pleistocene and Recent strand-line movement along the Atla
coast between Argentina on the south and New England on
north.

The discussion to follow will present evidence on Recent chang
the position of strand line, on the amount of change, and on the r
tions of the living coral to the basements on which they have for
for the West Indies from Antigua along the Caribbean arc to Cu
the Bahamas, the Bermudas, Florida, and Central America. Accou
of these areas will be followed by remarks on some other West Ind
Islands, on the Brazilian reefs, on the Argentine shore line, and on
shore line of the United States between Florida and Cape Cod.

[Footnote continued from page 271.]

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reef tract, Carnegie Inst. Washington Pub. No. 182, pp. 55–67, 1914.

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No. 13 (for 1914), pp. 227–233, 1915.

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1914), pp. 222–226, 1915.

Coral reefs and reef corals of the southeastern United States, their geologic history and their signifi
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ANTIGUA-BARBUDA BANK.

The islands of Antigua and Barbuda rise from a bank which is bounded by the 100-fathom curve and is 50 miles in length along a north-south line, and from 13 to 20 miles in width. Antigua is near the southern and Barbuda near the northern end, with water from 6 to 18 fathoms in depth between them. (See text fig. 9.)

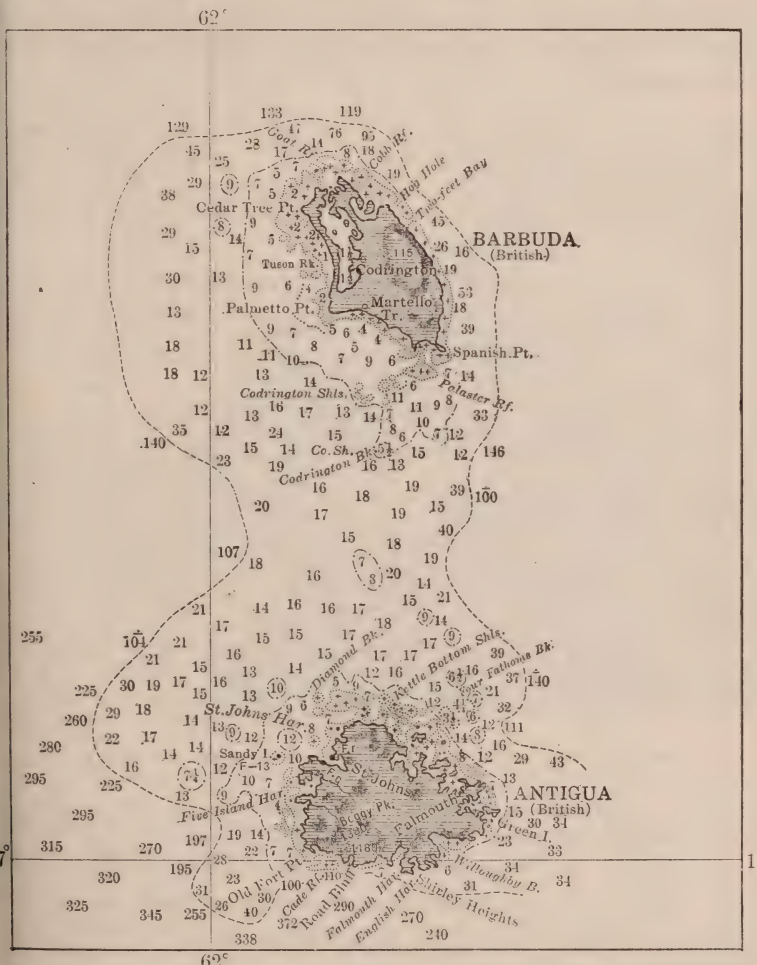


FIG. 9.—CHART OF ANTIGUA—BARBUDA BANK. FROM U. S. HYDROGRAPHIC CHART NO. 2318. SCALE, 1 INCH=ABOUT 12.8 NAUTICAL MILES.

The shore line of Antigua is deeply indented by numerous bays and harbors, as St. John, Five Islands, and Falmouth harbors, and Willoughby, Nonsuch, and Belfast bays (pl. 68, figs. A, B, and text fig. 10). The absence of terraces and elevated wave-cut cliffs is especially noteworthy. The discovery in St. John Harbor, at a depth of 20 feet below sea level, of a 4-foot bed of peat, which

is not composed of marine plants (according to Mr. C. A. Dav
adds confirmation to the inference from the indented shore line
the absence of elevated terraces and wave-cut cliffs that the
important movement of the strand line was one of submerge
Present sea-level relations have persisted long enough for the deve
ment of sea cliffs, in places 100 feet or more high, for the allu
fillings at the heads of the bays, and for the extension inlan
alluvial deposits along the streamways. There is some evidence
slight upward movement of the land, a few feet, less than 10, s
the submergence.

FIG. 10.—CHART OF PART OF EAST COAST OF ANTIGUA. FROM U. S. HYDROGRAPHIC CHART NO. 10

Barbuda, which is composed of limestone and has a maxim
height of about 200 feet, has no marked indentations of its sh
line; but Dr. H. A. Tempany informs me that fresh-water spr
emerge below sea level in the lagoon about one-half mile sout
Codrington village, a fact of significance in probably indica
submergence.

The similarity of the land mollusca of Antigua and Barbuda
support to the inference from physiographic data that these isl
were part of one land mass in Pleistocene time and have been sev
by submergence, and as the water between the islands is 18 fath
deep, the sea level must have risen at least that amount. A
merged steep slope off the southeast side of Antigua at depths
tween 100 and 150 feet accords with submergence to a depth of at l

fathoms, and indicates submergence of about 120 feet or 20 homs. (See fig. 11 below.)

Barrier coral reefs occur around Antigua off the mouth of Nonsuch y, off the southwest angle of the island, and there is a discon- uous barrier off the west side of the island. There are other reef tches, some of which are almost barriers. Barbuda has barrier fs, Cobb and Goat reefs, off its northern end.

These reefs of Antigua and Barbuda occur on a platform which has n submerged. That the platform or flat lying between Antigua d surrounding Antigua is in origin independent of the corals growing its surface is shown not alone by its continuity irrespective of presence of corals. That a land area existed between Antigua d Barbuda in Pleistocene time is clearly shown by the land mol- ca; while the submerged steep slope or scarp shows that the flat

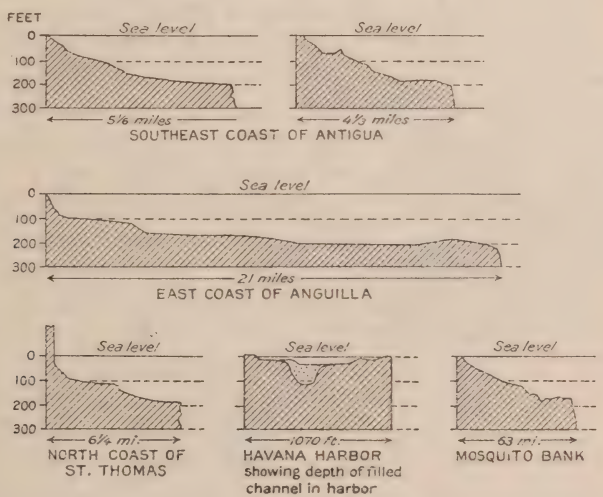


FIG. 11.—SUBMARINE PROFILES OFF WEST INDIAN ISLANDS AND ACROSS MOSQUITO BANK.

sted and was marginally cut by the sea while it stood about 120 t higher than at present.

ST. MARTIN PLATEAU.

J. W. Spencer has applied this designation to the plateau on which Bartholomew, St. Martin, and Anguilla stand. This plateau, as unded by the 100-fathom curve, is irregular in shape and is 75 les long by 45 miles wide. The maximum depth of water between Bartholomew and St. Martin is 16 fathoms and between St. rtin and Anguilla 14 fathoms. (See text fig. 12.)

The shore line of St. Bartholomew is indented, the indentations are ually divided by beaches into an inner or lagoon part and an outer y or harbor part (pl. 68, figs. C, D). The beaches may have en elevated between 3 and 5 feet. The lagoons behind the beaches

are the salt ponds of the island. There is an entire absence of e
vated terraces, unless some apparent shoulders on outlying islets, 1
actually visited by me, should be slightly elevated sea-cut bench
Wave-cut cliffs margin the rocky shores, and alluvial flats oc
around the heads of the bays.

The shore line of St. Martin is indented. Each reentrant into
land is usually divided by a transverse beach into an inner lagoon

FIG. 12.—CHART OF ST. MARTIN PLATEAU. FROM U. S. HYDROGRAPHIC CHART NO. 2318. SCALE ... INCH=ABOUT 12.8 NAUTICAL MILES.

salt pond and an outer bay portion; and alluvial flats margin ... heads of the reentrants and project inland between the hills. ... spurs along the shore are truncated by wave-cut cliffs (see pl. ... fig. A) and exhibit no definite terracing. Older beach rock was ... at the northeast end of Blanche Point, perhaps indicating sl ... differential uplift for that locality.

The shore line of Anguilla (see pl. 69, figs. B, D), although ... so conspicuously indented as that of St. Bartholomew and St. Ma...

indented, and a number of instances, Road Bay, for example, of e separation by beaches of an inner lagoon from an outer bay are esent. Three instances of inclosed basins having underground mmunication with the sea were noted (pl. 69, fig. C). No definite races are present and wave-cut cliffs are greatly developed.

That the last important change of sea level was by submergence the land is evident from the character of the shore line in St. Bartholomew, St. Martin, and Anguilla; and in Anguilla additional idence is afforded by the underground communication between closed basins in the limestone and the sea. Stable condition of the ore line for a considerable time is attested by the wave-cut cliffs, e development of the beaches, the alluvial fillings at the heads of ntrants into the landmass, and in St. Martin by the presence of terraced flood plains along the streamways.

In my paper on the littoral and sublittoral physiographic features the Virgin and northern Leeward Islands, referred to in the foot- te on page 272, I have shown that on the windward side of the St. artin plateau there is an outer deeper flat, 26 to 36 fathoms below a level, with a maximum length east and west of over 30 miles, and at this flat may be subdivisible into two subordinate terrace flats. e scarp on the landward side of the deeper flat in places is about feet high, in depths between 20 and 28 fathoms; above the deeper t is a shallower one, whose outer edge is about 20 fathoms under e sea (see text-fig. 11, p. 275). Other submarine evidence of sub- rgence in this area is given in my paper cited. At the time the ore line around the St. Martin Plateau was about 20 fathoms wer than at present, Anguilla, St. Martin, and St. Bartholomew ust have been united. The biologic evidence at present available not sufficient to be decisive, but all that is known accords with is interpretation. Notches on the outer edge of the plateau sim- ate hanging valleys and may represent the outer ends of valleys t while the sea stood about 40 fathoms lower than now; but the formation on these is too scant to justify more than a suggestion.

The hydrographic chart does not show well the reefs of these islands, r does the British Admiralty West India Pilot give a good descrip- n of them. Because of rough weather most of my own observa- ns were made from the shore. Coral reefs occur across the en- nces to most of the bays on the northeast and southeast sides of . Bartholomew; reefs are well developed on the east side of St artin, off North Point, and on the southeast side of Tintamarre and; and there are dangerous reefs off the southeast coast of nguilla and on the north coast of the east end of the island. Seal and reefs occur on a ridge extending westward from the northeast d of Anguilla. Some of these reefs are of the barrier type, as vigable channels lie between them and the shore, one at Forest int is an instance.

The reefs of the St. Martin Plateau are superposed on an a
cedent platform that was brought into its present relations to
level by geologically Recent submergence to an amount of abou
fathoms.

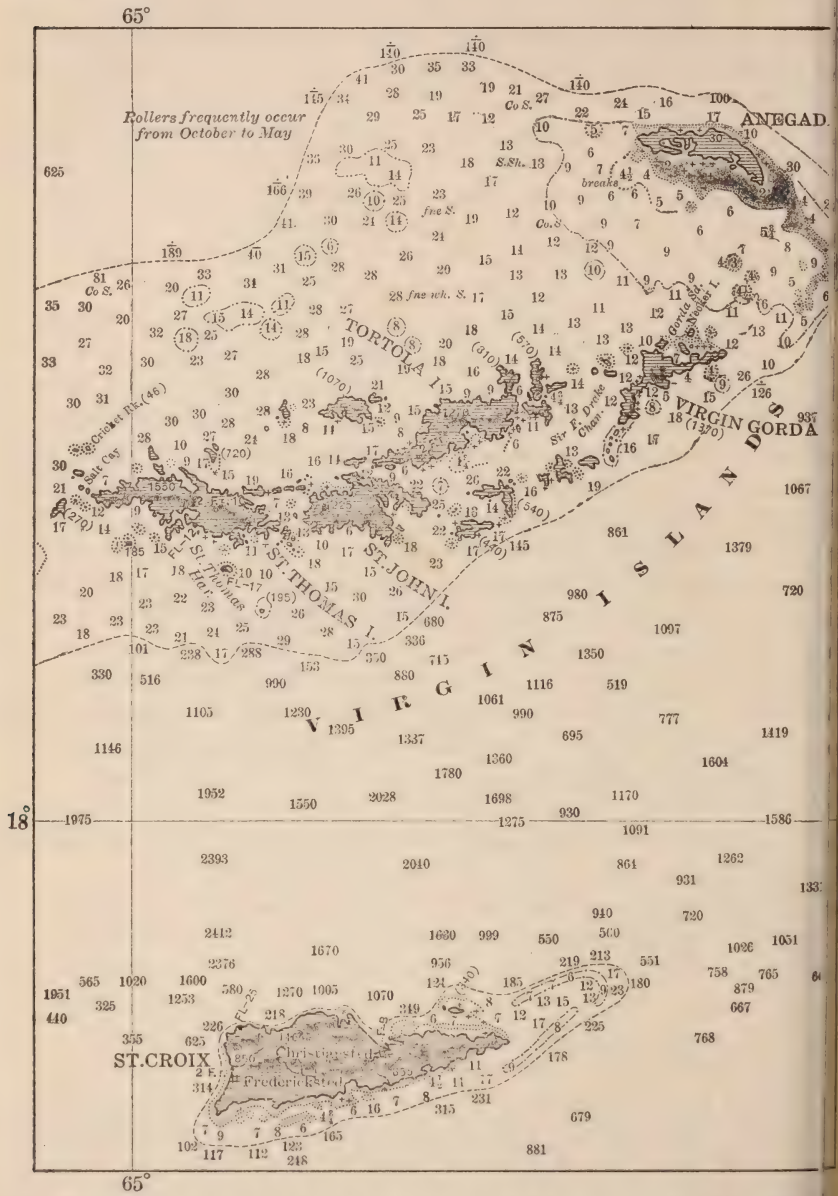


FIG. 13.—CHART OF VIRGIN ISLANDS AND ST. CROIX. FROM U. S. HYDROGRAPHIC CHART NO. 2318. ONE INCH=ABOUT 12.8 NAUTICAL MILES.

ST. CROIX ISLAND.

This island rises above a bank about 30 miles long and 10 miles wide. The distance from the shore to the 100-fathom curve is usually

s than three-quarters of a mile on the west end; and on the north e west of Sugar Bay the distance ranges from one-quarter to one-f mile. Off the south shore the distance to the 100-fathom curve places slightly exceeds 3 miles; off the east end for 7 miles the ter is less than 40 fathoms deep, while off the north coast the tform gradually narrows westward until near Salt River Point its lth is less than one-half mile.

There is a long, disconnected barrier reef off most of the south st, and barrier reefs are present off the north coast to a short dis-ce west of Christiansted. The indented, ragged coast line and depth of water on the platform so clearly point to the same con-sion as that already drawn from a study of Antigua, St. Bar-lomew, etc., that reiteration is not necessary.

VIRGIN BANK.

The Virgin group of islands consists of about 100 small islands and s (text fig. 13). The bank above which they rise is an eastward longation of that on which Porto Rico stands. The chart shows the ented coast line and the extensive, relatively shoal platform above surface of which the islands project. The maximum depth of ter between the islands is about 17 fathoms. St. Thomas well ibits the coastal phenomena to which attention has already been often directed—reentrants with alluvial fillings at their heads, erraced alluvial bottoms along streamways, and wave-cut cliffs on unterraced promontories (pl. 70, figs. A, B, C).

In my paper on some littoral and sublittoral physiographic features the Virgin and northern Leeward Islands, already referred to, it been pointed out that there are three terrace flats under the sea St. Thomas, St. John, Tortola, and Virgin Gorda (see text fig. 11, 275). On the leeward side the deepest lies between 26 and 30 oms in depth and is separated by a scarp or steep slope on its dward side from a flat ranging from 14 to 20 fathoms in depth, ch in turn is separated by a steep slope from a flat ranging from o 10 fathoms in depth. On the windward side the respective ths are 26 to 34 for the deepest flat, 14 to 20 fathoms for the rmediate flat, and 7 to 10 fathoms for the shallowest one. The rmediate flat is narrow or absent on the promontory tips on the dward side, while it is preserved on the leeward side, strongly gesting, if not actually proving, that the intermediate flat is older n the deeper one and was cut away in exposed places while the per one was forming. This evidence necessitates the deduction t in recent geologic time the Virgin Islands, except minor differ-ial crustal movement in the vicinity of Anegada, have been sub-ged to a depth of about 20 fathoms, and that they were previously ed to Porto Rico, a deduction completely corroborated by bio-

logic evidence, for Dr. L. Stejneger says in his herpetology of Pc Rico that "St. Thomas and St. John form only a herpetological pendix to Porto Rico," and Dr. P. Bartsch informs me that testimony of the land mollusca is the same as that of the rept and batrachians. Indentations at depths of about 40 fathoms in outer edge of the submarine bank simulate hanging valleys that n have been formed while the sea level was 40 fathoms lower thar present.

In the Virgin Islands there are three tiers of coral reefs, nam (1) on the outer edge of the deepest flat, (2) on the outer edge of intermediate flat, (3) within depths of 10 fathoms or less. The r could not have been formed on the deepest flat while the scarp the landward side of the flat was being cut, and the other reefs clearly younger than the basements above which they rise, for t basements existed and had had a complicated history prior the formation of the living reefs. In fact, the basements were land surfaces during at least a part of Pleistocene time.

CUBA.

The principal contributors to the literature on the shore-line p nomena of Cuba are W. O. Crosby,[1] Alexander Agassiz,[2] R. T. H Vaughan and Spencer,[4] and Hayes, Vaughan, and Spencer.[5] I h in papers cited on pages 271, 272 referred to some of the feature the Cuban shore line as bearing on the conditions under which the *ing coral reefs* off the shores of the island have formed. W. M. D has recently alluded to the origin of the pouch-shaped harbors,[6] here it may be well to direct attention to a criticism made by in his article cited in the foot note. He says:

> It is, however, worth noting that the embayments here considered have a different relation to the adjacent coral reefs from that found, according to H Vaughan, and Spencer, in the pouched-reef [7] harbors of Cuba: All the embayn I saw inside of sea-level barrier reefs in the Pacific islands occupy valleys older the reefs; but in Cuba the valleys, and still more the subsidence which dro them in producing the pouched harbors, are described by the above-named au as younger than the elevated reefs which inclose them; and such valleys do not a on the origin of the reefs, as appears from the following extract: * * *

The extract is followed by comment, then by a quotation f Crosby and one from Hill, after which he says: "Without additi

[1] Crosby, W. O., On the elevated reefs of Cuba, Bost. Soc. Nat. Hist. Proc., vol. 22, pp. 124–130

[2] Agassiz, A., A reconnaissance of the Bahamas and of the elevated reefs of Cuba in the steam *Wild Duck*, January to April, 1893, Mus. Comp. Zool. Bull., vol. 26, pp. 108–136, 1894.

[3] Hill, R. T., Notes on the geology of the island of Cuba, Mus. Comp. Zool. Bull., vol. 16, pp. 2 1895.

[4] Vaughan, T. W., and Spencer, A. C., The geography of Cuba, Amer. Geog. Soc. Bull., vol. 34, p 116, 1902.

[5] Hayes, C. W., Vaughan, T. W., Spencer, A. C., Report on a geological reconnaissance of Cub 123, 1902.

[6] Davis, W. M., A Shaler Memorial study of coral reefs, Amer. Journ. Sci., ser. 4, vol. 40, pp. 2 1915.

[7] "Pouched-reef harbors" are words not used in the publication under discussion by Professor

l study it is impossible to say which one of these views is correct, the features of the Pacific reefs that I have seen support Hill's lanation." I have twice published the statement that "Hayes, ghan, and Spencer have shown, as is evidenced by the pouch-ped harbors of the Cuban coast and filled channels, such as the merged filled channel in Habana Harbor, that the last movement he Cuban coast has been downward with reference to sea level," that "the platform on which *the Cuban reefs grow*[1] has been ght to its present position by subsidence." These remarks ly to the present living coral reefs and not to the elevated reefs, the conditions presented by the pouch-shaped harbor is only a of the evidence showing recent submergence of the Cuban shore

rofessor Davis's remark that "all the embayments I saw inside sea-level barriers in the Pacific occupy valleys older than the s" has no application whatever to the protecting effect a fringing may have on the shore of a land during elevation subsequent he formation of a fringing reef, thereby permitting erosional cies to operate more rapidly on the softer rocks lying back n the shore. The words in the Cuba report are: "Wherever the litions are favorable for the growth of corals a fringing reef is t * * *."

n preceding pages of this paper I have shown that there were l reefs in Cuba in middle Oligocene time; that there were reef ls in both upper Oligocene and Miocene time (this Miocene is d upper Oligocene in the Cuba report); and that there are stocene as well as living reefs. In the Miocene La Cruz marl in vicinity of Santiago the greatest abundance of reef corals is not e present head of Santiago Harbor, but it is seaward of the town antiago, east of La Cruz. (For a view seaward through the th of Santiago Harbor, see pl. 71, fig. B.) Whether the coral s are sufficiently abundant to have retarded erosion toward mouth of the harbor, while it was more rapid on the landward d I am not prepared to say. This, however, was not a fringing e should it be appropriately considered a reef.

to whether the elevated Pleistocene fringing reefs extended up he sides of the outflowing water at the harbor mouths, thereby taining restricted outlets, or whether channels have been cut ss the reefs after uplift, either of the alternatives is possible. he mouths of bays in Antigua, channels are maintained across g barrier reefs, which are tied to the shore at one end; while irgin Gorda, a barrier reef extends perpendicularly across the of the mouth of a submerged valley. These are living reefs, h have grown up during or after submergence and are younger

[1] Not italicized in the original. Note use of present tense, "*grow*."

than the valleys landward of them. However, as the eleva Cuban reefs under consideration are fringing reefs, it seems to more probable that they never extended across the harbor mout and I will add that the harbor basins had been formed, at leas large part, before the development of the now elevated fring Pleistocene reefs.

Crosby, in 1883, seems to have been the first one to recognize significance of the pouch-shaped harbors of Cuba. He says:[1]

* * * During this period of elevation, Cuba, like most rising lands, had harbors, but when subsidence began the sea occupied the channels and basins w had been excavated and cleared out by the rivers, and thus a large number of ha came into existence. * * * They are half-drowned valleys filled to a cons able depth with land detritus, conditions which could not exist if the land was r or had risen.

There are very many pouch-shaped along the Cuban coast. following table presents information on 15 of them:

Principal Cuban harbors.

Name.	Shape.	Maximum width, sea-miles.[1]	Maximum known depth in channel or harbor.	Channel length, sea-miles.	Channel within narrowest part.	Height of cent lar	
						East side.	
NORTH COAST.							
			Feet.		*Feet.*	*Feet.*	
Bahia Honda	Palmately digitate	3.00	[2] 59	1.50	2,180	30–40	
Cabañas	Trilobate	6.00	79	.50	1,825	160	
Mariel	Irregularly digitate	1.50	[3] 72	.60	900		
Habana	Trilobate	[4] 2.00	[5] 60	.75	470	200	
Nuevitas	Bilobate	7.00	[6] 137	4.38	1,400	Flat.	
Padre	Irregularly bilobate	7.50	75	1.75	900	Flat.	
Banes	Palmately digitate	3.25	85	1.50	450	[8] 100	
Nipe	Unequally bilobate		[10] 234	[5] 2.00	2,900	[8] 200	
Livisa and Cabonico	do	8.00	[11] 168	.50	1,300	50–75	
Tanamo	Irregularly bilobate	5.38	156	.63	600	120–176	
SOUTH COAST.							
Baitiqueri	Trilobate head	.60	[12] 33	.18	300	590	
Guantanamo	Irregularly dumb-bell shaped.	5.00	59	3.75	6,530	436	
Santiago	Unilateral	1.00	68	.38	675	230	
Enseñada de Mora			58				
Cienfuegos	Unilateral	4.25	[13] 139	2.13	1,200	130	

[1] 1 sea-mile=6,081 feet.
[2] 110 feet outside at channel mouth.
[3] 90 feet in channel mouth.
[4] About.
[5] Submerged channel 100.
[6] 100 feet frequent.
[7] Coral rock according to A. Agassiz.
[8] South.
[9] North.
[10] 180 feet and over frequent.
[11] 150 feet frequent.
[12] 78 feet at mouth.
[13] 214 feet off Pta. Pasa Caballos.

It is important to note that where the harbors are digita shape, Bahia Honda for instance, one or more streams enter digitation, and that the mouths of the streams are either emb or, in places, swamps and delta plains have formed. The p shaped harbors are not the only indentations of the shore lin the lower courses of all the larger streams are more or less emb

[1] Crosby, W. O., On the elevated reefs of Cuba, Bost. Soc. Nat. Hist. Proc., vol. 24, pp. 124–130 83.

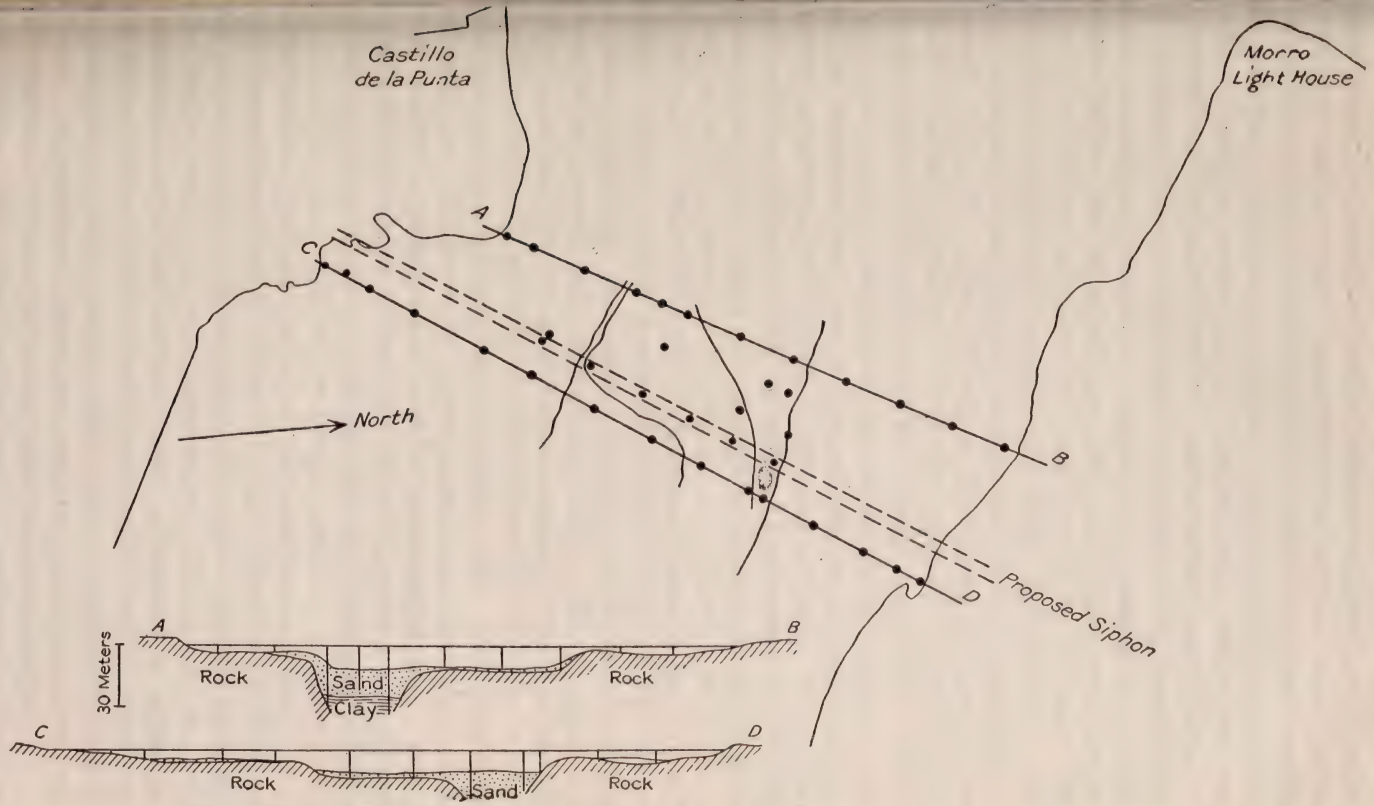


FIG. 14.—PLAN AND CROSS-SECTION OF FILLED CHANNEL IN HABANA HARBOR. AFTER HAYES, VAUGHAN, AND SPENCER.

How are the harbors to be explained? Doctor Hayes and I believed we found the answer in the conditions at present exist along Yumuri River, near Matanzas. The river here empties in the sea through a narrow gorge cut through Miocene limestone a marls (see pl. 71, fig. C). The top of the gorge is 200 feet abo sea level, while farther back from the stream altitudes of 400 f or slightly more are attained. Above the gorge, the Yumuri a its tributary, Rio Caico, have sunk their courses through the li stone, have removed it, and have developed wide, almost base-le valleys (see pl. 71, fig. D), on the underlying softer sandst and shale. If this basin were depressed sufficiently to let the into it through Yumuri gorge a pouch-shaped harbor would result

Additional evidence bearing on the problem of the origin of th harbors was obtained from records of borings. Mr. C. A. Knowlt an engineer at Santiago, reported to us that in boring wells in valley of San Juan River, 3 miles southeast of Santiago, he fo at a depth of 70 feet below sea level what appeared to be stre gravel. Even more convincing evidence was obtained in Hab Harbor. In the preparation of plans for a sewerage system Military Governor had a series of borings made across the har This harbor occurs in a rather wide valley surrounded by s which slope upward from sea level to an altitude of about 200 f The borings revealed a submerged terraced valley within the w valley and in the middle of the inner valley a channel reachi depth of more than 30 meters (about 100 feet) below sea level text-fig. 14). The depth of the first flat above the sides of channel is about 13 meters (about 42 feet) below sea level. This is now covered with sand and the submerged channel is filled th sand and clay. There are at present no known processes whe such a channel and terrace could be developed and then bu except by a higher stand of the land enabling a stream to c trench and develop a terrace, followed by a lower stand of the which submerged both the channel and the terrace and resulte in their burial by sediment deposited over them.

It appears to me that there is no escape from the interpreta n, made first by Crosby, that the pouch-shaped harbors are drow d drainage basins. Before the accumulation of the data by H s, Spencer, and me, Hill endeavored to explain them without a ft in height of strand-line, but after the additional information as presented to him he abandoned his interpretation and accepted s. There is a statement to this effect in a manuscript by him now in y possession, and this citation is made with his authority.

The factors producing the peculiar form of the harbors will ow be briefly considered. According to Crosby, Hill, and the acc nt in our report on Cuba, fringing reefs are supposed to have restri ed

mouths of the streams, either by growing up to the edges of the flowing water, a channel thereby being maintained, or because of their greater hardness they offered greater resistance to erosion than the softer rocks on their landward side. It is my present opinion that the hypothesis of the reefs having more than a secondary importance in the development of these features must be discarded for the following reasons: First, that such physiographic forms are in no wise dependent on the presence of coral reefs is shown by their frequency in areas underlain by Cretaceous limestones in Texas. Helcoat Valley in the southwest quarter of the Nueces quadrangle, Texas, is such a basin, with a narrow outlet into Nueces River. This is only one of a number of instances that might be given. In physiographic form this basin and its outlet resemble the pouch-shaped harbors of Cuba. Second, there is no evidence that corals had any more influence in Cuba than in Texas, for instance, Yumuri gorge at Manzas is about 200 feet deep. The highest important elevated coral reef rocks occur at an altitude of about 35 feet above sea level off the sides of the stream mouth. The stream has cut and maintained a gorge through about 165 feet of limestone and marl which are topographically above the reef and which are not coral reef rocks, but which are bedded and were formed by other agencies. Other instances of these relations might be given.

The conditions around the Habana Harbor are interesting in this connection. Limestone of upper Oligocene or Miocene age occurs at the Morro and forms the higher land along the shore east of the city, and it outcrops at lower altitudes in the western part of the city; but the drainage at the south end of the harbor has cut through the limestone and exposed the underlying rocks, serpentine, rotten diabase, etc.; and that underground solution is active is indicated by the presence of springs along the serpentine contact. The conditions are here favorable for erosion by both mechanical cutting and solution in the area lying behind, while a channel has been maintained across the limestone on the sea front. This basin after it was outlined was submerged.

It is intended to give a much fuller discussion of the Cuban harbors in a paper now almost ready for press. The differences in form, and the causes to which the differences are due, are worthy of far more detailed treatment than is practicable in this place. I will end this part of the present discussion by saying that corals have in certain instances played a subordinate rôle by narrowing the mouth of a harbor and by preserving a constricted outlet. That the outlets of the basins here considered were constricted by reef rocks, now elevated, is shown by the conditions in Habana and Santiago harbors, and that similar constriction is now taking place by similar agencies

is exemplified in many of the West Indian Islands. As the c
rock is usually harder than the rocks on which it rests, after
emergence it protects the narrow exit behind which erosion is n
rapid and enlarges the basin.

From the remarks already made it appears unnecessary to dis
specially which are the older—the drainage basins occupied by
harbors or the coral reefs now elevated about 30 feet. Howe
that the Santiago basin is older than the coastal soborruco is sh
by finding the soborruco within the harbor mouth; and as I fo
recent species of reef corals, apparently in place, on the east sid
Habana Harbor, south of the Morro, at a height of 30 feet above
level, the 30-foot reef seems to extend into the mouth of Hab
Harbor. The valleys are clearly older. On page 264 of this pap
special point was made of the unconformity between the elev
Pleistocene reefs and the underlying Miocene material and the
ference was drawn that the reefs were formed during subsidence a
erosion of the basement under them. This is precisely the interp
tion Professor Davis had made of the relations in the elevated
of the New Hebrides, but it seems such relations may develop in
same cycle, and, in my opinion, they are of slight importance in
bearing on the general theory of coral-reef formation.

The Isle of Pines furnishes important information on changes i
level around Cuba. This island is nearly opposite Habana, 60
south of the south coast of Cuba, from which it is separated by w
less than 10 fathoms deep. It comprises two parts, a southern w
is mostly swamp, and a northern which is topographically hig
The surface of the northern division is mostly a plain, real
peneplain (see pl. 72, fig. A), above whose surface stand monadn
of harder rocks (pl. 72, fig. B). This island is very different
the main island for, as no Tertiary or Cretaceous marine dep
are known to occur on it, it appears to have remained abov
level during these periods, but it has experienced the later cha
of sea level which affected the larger island and during Pleisto
time it was joined to Cuba. The peneplain was formed at a l
level than that at which it now stands, it was then sufficiently upl
to permit streams to cut into it, and has then been depre
thereby drowning the mouths of the streams, but not bringing
plain surface so low as it formerly stood (pl. 72, fig. C).
coast line of the Isle of Pines and that of Cuba immediately nor
it both are indented by the embayment of stream mouths thr
geologically recent submergence.

That the Isle of Pines was joined to Cuba during Pleistocene
is shown convincingly by its land fauna. Every species of re
except one, found on it, Dr. L. Stejneger informs me, is know
occur in Cuba, and two species of the mammalian genus *Capr*

common to both. Dr. Paul Bartsch tells me that the Isle of es is only "a chunk of Cuba" and that its land Mollusca represent unal area as closely related to the faunal areas of Cuba as are different faunal areas in Cuba to one another; that is, faunally, Isle of Pines is simply a portion (a faunal area) of Cuba. There-, it is clear that the Isle of Pines has been severed from Cuba in latest Pleistocene or Recent geologic time.

Practically all the Cuban shore line has now been considered except t on the north side of the Province of Pinar del Rio, within the orados Reefs. Guadiana Bay is a nearly typical estuarine em-ment, while slighter embayment of other stream mouths is icated, and lines of islands extend seaward from some headlands. shore line clearly indicates submergence. Mr. J. B. Henderson Doctor Bartsch, however, tell me that there is positive evidence minor uplift west of Guadiana Bay.[1]

The Cuban shore line as a whole shows evidence of Recent or latest istocene submergence, and this submergence has influenced the dern coral-reef development.

Regarding the amount of Recent submergence of the Cuban shore , reference to the table on page 282 shows that there is close ac-dance in the depths of the channels or harbors, except certain s that will be discussed later. These indicate that prior to the submergence the land stood about 100 feet or slightly more, ut 20 fathoms, higher than at present. The amount of emergence uld establish a broad land connection with the Isle of Pines.

The discrepant harbors are Nuevitas Bay, which shows an excess only about 27 feet, Nipe and Tanamo bays, and the channel ling from Livisa and Cabonico bays, on the north coast, and Cnfuegos on the south coast. The harbors with the discrepant ths on the north coast all occur on the north side of the Province Oriente and at the eastern end of the Province of Camaguey. ey seem to indicate deeper submergence than at other places and t the submergence has not been uniform in amount for the entire st. However, the depths do not contradict a Recent rise of sea el to an amount of about 20 fathoms. The harbor of Cienfuegos uld be expected to be abnormal, for the fault line which runs thward from Cape Cruz intersects the shore line at its mouth (see text-fig. 15). It is possible that structural relations have also uenced the depths in the other harbors and channels that are crepant. Regarding these it will be said that except Nuevitas rbor they occur within a linear distance of 31 miles. Nipe Harbor, westernmost of the group, lies on the north side of Loma de las, while it, Livisa, Cabonico, and Tanamo harbors all are on north side of Sierra Cristal.

[1] Henderson, J. B., Cruise of the *Tomas Barrera*, pp. 161–164, New York, 1916.

The great extent and relatively uniform height of a coral-
terrace between 30 and 40 feet above sea level favors the interpr
tion that the geologically Recent shift in position of strand line
been without pronounced crustal deformation.

The relations of the off-shore reefs to the platforms on which t
grow will now be briefly considered. A detailed description of
reefs is unnecessary here, as it would be only a repetition of
already given by A. Agassiz [1] and the accounts contained in
West Indies Pilot.[2] It need only be stated that the best develo
off-shore reefs on the north coast are the Colorados Reefs, betw
Bahia Honda and Cape San Antonio; and that off the south c
the best are those between Trinidad and Cape Cruz and those
and west of the Isle of Pines. Mr. John B. Henderson has devo
attention to the Colorados Reefs in his "Cruise of the *To*
Barrera." Have the reefs off the south coast grown up on
surface of preexistent platforms or are the platforms due to infil
behind a reef during subsidence?

The area between Trinidad and Cape Cruz will be consid
first. The fact that the reefs form disconnected hillocks or mou
sometimes of mushroom shape, above a plain surface, which in pl
is 50 miles wide along a line perpendicular to the shore, while
the seaward side of the reefs there are large areas of shallow platfo
without any margining reefs, seems conclusive evidence against
platform having been caused by infilling behind reefs.

The following, in my opinion, is the correct explanation: The
toral geologic formations from Cape Cruz to Trinidad are mo
upper Oligocene or Miocene marls and limestones which dip u
the sea at relatively low angles. They dip into the Cauto Val
which is a gently pitching syncline, and into its seaward contin
tion, the Gulf of Guacanayabo. The embayment northeast of B
Grande passage is probably also synclinal in structure. The abr
undersea termination of the platform is most reasonably explai
by a submarine fault which runs from Punta Sabanilla, at the mo
of Cienfuegos Harbor, to Cape Cruz. The coral reefs have gr
up on the surface of a plain underlain by geologic formations t
were gently tilted seaward and faulted along the line indicated.

That the Isle of Pines was joined to Cuba during Pleistocene t
has, I believe, been shown in a convincing manner. As the Mioc
and upper Oligocene formations from Batabano to Pinar del Rio
under the sea at low angles they must underlie the flat botto
the Gulf of Batabano. That the submarine slope from East Gu
Key to off Cape San Antonio is determined either by a fault or b
very steep flexure is clearly indicated, as off the south shore of

[1] Bull. Mus. Comp. Zool., vol. 26, pp. 133–136, 1894.
[2] West Indies Pilot, vol. 1, pp. 199–332, 1913 (U. S. Hydrographic Office).

FIG. 15.—CHART OF SOUTH COAST OF CUBA, SHOWING SUBMERGED FLAT AND INFERRED FAULT LINES. FROM U. S. HYDROGRAPHIC CHART NO. 1290.

Isle of Pines the descent from the shore in 9 sea-miles is 13,080 f a slope of about 1 in 4. The Gulf of Cazones appears to have l outlined by faulting. This shelf differs from the one considere the preceding paragraph, in that the Isle of Pines, whose are about 1,200 square miles, stands on its outer margin, and appare has affected the course of the fault. However, there was here an undersea flat, which was produced by the gentle seaward til low-lying geologic formations, and its outer margin was also de

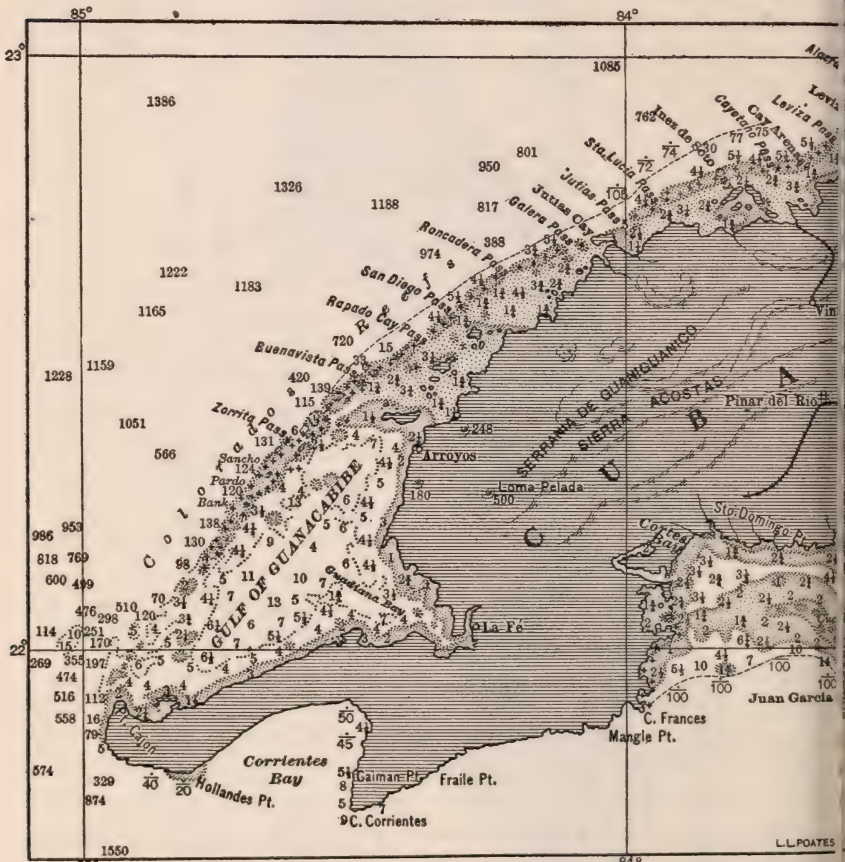


FIG. 16.—CHART OF COLORADOS REEFS, CUBA. FROM U. S. HYDROGRAPHIC CHART NO. 966

mined by faulting. The living reefs are growing on its subme unfaulted part, above which they rise as disconnected patches a broken barrier.

The Colorados reefs (text-fig. 16) grow as patches of barrier or upon a shelf, which, according to Henderson, largely consist coral rock that had been uplifted above the sea and then depres[1]

The conditions under which the Cuban offshore reefs are gro can be very easily summarized, as follows: (1) They are superp

[1] Henderson, John B., Cruise of the *Tomas Barrera*, pp. 62–64, 126–130, 1916.

flats submerged in geologically Recent time; (2) the amount of submergence of Cuba was about 100 feet.

BAHAMAS.

lexander Agassiz has in his reconnaisance of the Bahamas[1] the owing very significant statement:

y we not to a great extent measure the amount of subsidence which must have n place at certain points of the Bahamas by the depth attained in some of the lled ocean holes, as marked on the charts? Of course we assume that they were in the aeolian strata to the same process which has on the shores of many islands ed potholes, boiling holes, banana holes, sea holes, caverns, caves, sinks, cavities, holes, and other openings in the aeolian rocks. They are all due more or less to ction of rain percolating through the aeolian rocks and becoming charged with nic acid, or rendered acid by the fermentation of decomposed vegetable or ani- matter or by the action upon the limestone of sea water or spray under the most ing conditions of elevation and of exposure. None of them have their upper ings below low-water mark, though some of them may reach many feet below water level. Ocean holes were formed in a similar way at a time when that part e bank where they exist was above high-water mark, and at a sufficient height e that point to include its deepest part. The subsidence of the bank has carried evel of the mouth and of the bottom of the hole below high-water mark.
om the description of the strata which crop out upon the banks in the vicinity of of the ocean holes at Blue Hole Point, there seems to be little doubt that the fication characteristic of the aeolian rocks has been observed.

he deepest of the holes mentioned by Agassiz has a depth of 38 oms, "in the extension of the line of Blossom Channel leading n the Tongue of the Ocean up on the bank."

have had opportunities to study such "holes" or solution wells, ve sea level in Florida and have examined many of them, both ve and below sea level, in the Bahamas. Mr. E. W. Forsyth nded other "holes" and reported the results to me.[2] The depths of holes range from about 2 fathoms to as much as 33 fathoms, the eest hole in Fat Turtle Sound, North Bight, Andros Island, nded by Mr. Forsyth. As in my opinion Agassiz's deduction as o he origin of these holes is incontrovertible, they indicate a stand f he land during Pleistocene time at least 228 feet higher than at r ent. Shattuck[3] and Miller accept a higher stand of 300 feet, owed by submergence of 300 feet, and conclude that this move- nt in strand-line position was followed by emergence, to an amount eveen 15 and 20 feet. From my own experience in the Bahamas h last change in the position of strand line was accompanied by nor differential crustal movement. For instance, at Nicollstown Lit, Andros Island, a sea cave stands at such a height above the se as to show conclusively an elevation of 18 feet above the position

[1] s. Comp. Zool. Bull., vol. 26, pp. 41–42, 1894.
[2] ughan, T. W., Carnegie Inst. Washington Yearbook No. 13, p. 229, 1915.
[3] ttuck, G. B., and Miller, B. L., Physiography and geology of the Bahama Islands, The Bahama Isla s, pp. 19, 20, 1905.

at which it was formed; but 4,000 feet southeast of the cave elevation is only about 4 feet in amount. I have given more in mation on this minor uplift in the paper referred to in the footnc

Agassiz, Shattuck, and Miller, and I agree as to the geol cally Recent submergence of the Bahamas.

The accompanying diagram (text-fig. 17) indicates the relat of the barrier reef off the west side of Andros Island to the platf on the edge of which it is growing. This reef is growing on the e of a platform that had stood above sea level at least as much as feet. It was perforated by solution wells and then submerged. perforations in the platform show that it antedates the barrier r and that its formation is not dependent on agencies associated v the presence of the reef. There is here another instance of a formed during or after submergence, and superposed on the sur of an antecedent platform.

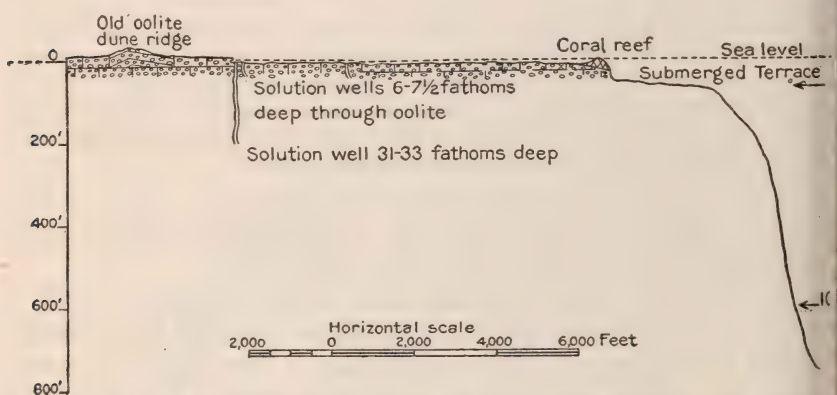


FIG. 17.—DIAGRAMMATIC SECTION ACROSS THE BARRIER REEF, ANDROS ISLAND, BAHAMAS.

The relative importance of the constructional rôle of the li reef will be briefly mentioned. The Pleistocene oolite of the Baha is not coral-reef rock, as was contended by A. Agassiz. It is compc of calcium carbonate chemically precipitated on extensive subma flats.[2] I have several times published the estimate "that on An Island, Bahamas, the ratio of the constructive work of the pre reef to that of agencies that previously resulted in the formatio the Pleistocene oolite is approximately as 1 to several thousand. as a constructive agent, chemical precipitation has been sev thousand times more effective in forming limestone than corals."[3]

Before passing to the discussion of the next area it should pointed out that the amount of submergence of the Bahamas,

[1] Carnegie Inst. Washington Yearbook No. 13, p. 229, 1915.

[2] For the most recent discussions of this subject, see Vaughan, T. W., Some shoal-water bottom sa from Murray Island, etc., Carnegie Inst. Washington Pub. 213, pp. 277–280, 1918; Chemical and o deposits of the sea, Geol. Soc. Amer. Bull., vol. 28, pp. 933-944, 1918.

[3] Wash. Acad. Sci. Journ., vol. 4, pp. 26, 27, 1914; Carnegie Inst. Washington Pub. 213, p. 279, 191

is greater than that, about 120 feet, indicated for the areas dy considered, unless the notches in the outer edges of the St. in Plateau and the Virgin Bank really indicate a position of sea 40 fathoms lower than present sea level.

BERMUDAS.

exander Agassiz has given a good account of proto-Bermuda, that the extent and general physical character of the Bermudas pre- s to the submergence that has left the group in very nearly the in which we now know it.[1] Recently Prof. L. V. Pirsson has con- ted two highly valuable articles to the literature on the geology ie islands, basing his interpretations largely upon a study of les from a well bored in Southampton Parish, on the slope of a about a mile west of the lighthouse on Gibbs Hill, from a height 5 feet above sea level to a depth of 1,413 feet below the surface, a depth of 1,278 feet below sea level.[2]

ere were penetrated in the well mentioned three major classes aterial, as follows: (1) From the surface to a depth 383 feet v it, limestone; (2) from 383 feet to 600 feet, oxidized volcanic rial; (3) below 600 feet to 1,413 feet, with one slight exception, tic, usually black lava. Pirsson concludes the first of his two es with the following statement:

> It ppears to the writer that what has been learned regarding the history of the uda volcano has an important bearing on the question of the way in which the ms on which coral islands, barrier reefs and atolls are situated, have been rl. There is of course nothing new in the idea that these may be volcanic in g only in Bermuda we have once more a positive demonstration of the fact. We lso seen that, provided the volcanic masses are of sufficient antiquity, they ven though of great size, have been reduced to sea level, furnishing platforms e extent. As mentioned above, such masses reduced to sea level would con- o project from the ocean abysses indefinitely and many of them may be of great c age. There is nothing in the mere size of any of the atolls of the Pacific which preclude their being placed on the stumps of former volcanic masses; it is not ed to assert by this that the foundation in every case is necessarily a volcanic e. If such masses have once been brought down to sea level and continue to exist at level changes within limits from time to time by warpings in different places sea floor, or by an accumulation of ice on the lands and its melting, as suggested y, then conditions of shallow water over them may be established suitable for olonization by those organisms concerned in the production of the so-called eefs, which may be formed under the conditions postulated by Vaughan.

It was the understanding between Professor Pirsson and me that should prepare a report on the calcium-carbonate samples. The ing is a preliminary statement, accompanied by determinations the Foraminifera by Dr. Joseph A. Cushman.

Agassiz, Alexander, A visit to the Bermudas in March, 1894, Mus. Comp. Zool. Bull., vol. 26, pp. 273–
Pl., 1895.

Pirsson, L. V., Geology of Bermuda Island, I. The igneous platform, Amer. Journ. Sci., ser. 4, vol. 38,
1906; II. Petrology of the lavas, Idem., pp. 331–344, 1914.

Preliminary description of the limestone samples and list of species of Foraminifera the Bermuda well.

No. of specimen and depth below surface.	Description.	Species of Foraminifera.
1 (0–6 feet)	Light cream-colored limestone; mixture of calcite and aragonite; most of the constituent particles angular; largely or mostly broken remains of organisms; occasional small round grains 0.10 mm. or less in diameter, may be aggregates of chemically precipitated calcium carbonate. Largely or mostly an organic limestone.	*Textularia agglutinans* d'Orbi *Polystomella striatopunctata* & Moll. *Polystomella* species. *Amphistegina lessonii* d'Orbig *Quinqueloculina reticulata* d'O *Q. oblonga* Montagu. *Q. auberiana* d'Orbigny. *Peneroplis pertusus* Forskål. *Orbiculina adunca* Fichtel & M
2 (61–110 feet)	Light cream-colored limestone; mixture of calcite and aragonite; constituent particles mostly angular, Foraminifera and broken tests of other organisms present; a few rounded grains 0.04 mm. or less in diameter, may be aggregates of chemically precipitated material. Largely or mostly an organic limestone.	*Textularia agglutinans* d'Orbi *Polystomella striatopunctata* & Moll. *Polystomella* species. *Amphistegina lessonii* d'Orbig *Quinqueloculina reticulata* d'O *Q. auberiana* d'Orbigny. *Orbiculina adunca* Fichtel & M
3 (110–216 feet)	Light cream-colored limestone; mixture of calcite and aragonite, apparently but little aragonite; largely a recrystallized limestone, without conspicuous grains; some small pockets contain pulverulent calcium carbonate; some pieces granular. A few grains 0.05 to 0.8 mm. in diameter resemble small oolite grains. The rock is mostly a foraminiferal limestone, the Foraminifera embedded in a cryptocrystalline matrix.	*Clavulina angularis* d'Orbigny *Planorbulina larvata* Parker & *Truncatulina* species. *Polystomella striatopunctata* & Moll. *Amphistegina lessonii* d'Orbig *Triloculina* cf. *T. circularis* mann. *Orbiculina adunca* Fichtel & M
4 (216–241 feet)	Whitish limestone, very slight yellowish tinge, some blackish particles; mixture of aragonite and calcite; specimen consists mostly of broken rock fragments; an occasional small pebble, one 2.5 mm. as maximum diameter; constituent material largely organic, Foraminifera, fragments of mollusks, shells, etc. Most small particles angular; a few less than 0.12 mm. appear oolitic. One 0.09 by 0.17 mm. in size had form of an oolitic ellipsoid. Mostly an organic limestone.	*Truncatulina* species. *Pulvinulina canariensis* d'Orb *Polystomella striatopunctata* & Moll. *Polystomella* species. *Amphistegina lessonii* d'Orbig *Triloculina linneana* d'Orbigi *Orbiculina adunca* Fichtel & M
5 (241–286 feet)	Whitish, faintly yellowish, pulverulent limestone; mixture of calcite and aragonite. Comparatively few tests of organisms, some Foraminifera, many small rounded grains and cryptocrystalline material. Some of the round grains appear oolitic; one of these is 0.11 by 0.15 mm. in size. It appears that a considerable proportion of this bed is a chemical precipitate.	*Bolivina* species. *Truncatulina* species. *Discorbis vilardeboana* d'Orbi *Amphistegina* species. *Quinqueloculina reticulata* d'C *Biloculina* species.
6 (286–331 feet)	White, pulverulent limestone; mixture of calcite and aragonite. No organic tests were observed. Round grains up to 0.1 or 0.2 mm. appear to be oolite; small round grains 0.04 mm. in diameter. Much cryptocrystalline material. This bed appears to be largely a chemical precipitate.	None reported.
7 (331–341 feet)	White, friable limestone; mixture of calcite and aragonite. Round grains which range in diameter from 0.22 to 0.45 mm., may be oolitic. Small grains, 0.09 mm. in diameter seem definitely oolitic. Besides the rounded, there are broken angular grains and much cryptocrystalline material. Few or no organic tests. This appears to be largely a chemical precipitate.	*Amphistegina* species.
8 (341–383 feet)	Light-colored, earthy, yellowish-gray, impure limestone; some iron pyrites; mostly calcite, if aragonite is present the proportion is small. Many Foraminifera, *Nummulites*, fragments of coral, Bryozoa, etc.; many rounded grains which may be detrital; no definitely oolitic grains were observed. A thin section shows many Foraminifera embedded in a cryptocrystalline matrix. This bed is an impure, foraminiferal, shoal water limestone. It may contain some chemically precipitated material.	*Nummulites* species.

s examination reveals three kinds of limestone, the uppermost ich subsequently may be subdivided. The three divisions are lows:

cimens 1–4 (0–241 feet) represent a limestone which is largely or y of organic origin, but which may contain a few grains of cally precipitated material. This corresponds to the upper l division recognized by Cushman.

cimens 5–7 (241–341 feet) represent a pulverulent limestone, osed of rounded grains imbedded in finely crystalline material. rains in their size and shape resemble oolite, and some grains d with greater or less distinctness suggestions of oölitic struc- The foraminiferal fauna is meager, but it differs from that of nens 1–4 and the underlying bed represented by specimen 8. ms safe to draw the inference that this division of the lime- is in part, at least, a chemical precipitate.

cimen 8 (341–383 feet) represents an impure, foraminiferal, r limestone, or a calcareous marl, in which there may be some cally precipitated material. This bed is the uppermost in the *Nummulites* reported by Cushman occur. It was also in the underlying bed No. 9, 383–393 feet.

Probable geologic age of the limestone in the Bermuda well.

[Height of well mouth above sea level, 135 feet.]

amples.	Probable geologic age.
-241 feet	Recent and Pleistocene.
41–286 feet	Pliocene or Miocene.
31–341 feet	Nothing determinable.
41–393 feet	Oligocene or Eocene (*Nummulites*).
93–485 feet	Eocene? (no *Nummulites*).

outline of the geologic history of the Bermudas subsequent volcanic activity seems to be as follows:

tor Cushman's identification of the Foraminifera from the rmuda well shows the presence of an undetermined species of *yomella* between 393 and 480 and between 480 and 485 feet. e depths are well down in the oxidized zone and indicate marine ditions which persisted throughout the deposition of the super- nbent material. Other Foraminifera occur between 383 and 393, them being a species of *Nummulites*, which was also obtained in the basal bed of limestone at a depth of 341 feet. As the *Nummulites* is, according to our present knowledge, confined t upper Eocene and Oligocene formations in the southeastern it l States and the West Indies, the inference may be drawn that rmuda samples between 341 and 393 feet probably represent a ic formation of either Eocene or Oligocene age, and that those 393–485 feet represent a formation of probably Eocene age.

Until the specimens of *Nummulites* from the Bermuda well l
been identified with species of known stratigraphic position a r
definite statement can not be made. It appears safe to assig
Eocene or pre-Eocene age to the Bermudian volcanic activity.

The calcareous sediments, therefore, began to accumulate
submerged volcanic basement in Eocene or lower Oligocene t
and the submergence progressed until the basement, in prob
Miocene time, was entirely blanketed by calcareous deposits
feet thick, which differ in their physical aspect both from the ur
lying nummulitic rock and the overlying organic limestone.
rock is probably in considerable part a chemical precipitate.
well samples indicate no stratigraphic break at either its top
base.

The limestone from a depth of 241 feet to the surface is a sh
water, organic deposit, in which living species of Foraminifera
abundant. Its age is probably Pleistocene, although the lower
may prove to be Pliocene. The shoal-water nature of the limes
indicates continued slow subsidence.

The subsidence which apparently had been interrupted b
period of emergence since Oligocene time was succeeded in Ple
cene time by uplift to an amount of probably more than 100
All the surface rock of the Bermudas except some in areas of o
elevation is considered by the geologists who have visited the isl
to be eolian deposits. However, certain of the published illus
tions suggest that in some exposures there are in the bedding
zontal planes intersecting the inclined layers. Cross-bedding bet
horizontal planes is a structure characteristic of shoal-water or l
deposits but not of eolian deposits. A more critical study o
bedding of the Bermudian rocks may discriminate elevated
bedded water-laid and eolian deposits. However this may be
period of uplift under consideration was the time of the Greater
muda, which has been admirably described by William North
A. Agassiz, and A. E. Verrill. According to the latter, the ar
Greater Bermuda was somewhat more than 230 square miles, or
11 times that of the present land surface, which is estimated as
ing an area of 19⅓ square miles.[1] The evidence indicates tha
elliptical area inclosed by the outer reefs was entirely above sea
as perhaps also were the surfaces of Challenger and Argus bank

The last important change in the relations of sea level wa
Verrill has so ably shown, submergence to an amount of abou
feet, reducing the land area from that of 230 square miles durin
period of Greater Bermuda to that of 19⅓ square miles, the pr

[1] Conn. Acad. Arts and Sci. Trans., vol. 12, p. 52, 1905.

in. The evidence is not decisive as to there having been a slight ergence, of 6 to 10 feet, since the great submergence.

s Verrill has shown, the Bermuda limestone is composed not of al débris, except in a subordinate proportion, but is made up of ken, more or less triturated, calcareous tests, largely of mollusks. designates the material as "shell sands." The Bermudas are, refore, inappropriately called "coral islands." The recent corals growing on a foundation of older lime rock, brought into its sent relation to sea level by submergence.

n that the last dominant change in the position of its strand line by submergence, Bermuda accords with the Florida coast, the amas, Cuba, and most of the smaller West Indian islands.

FLORIDA.

trand-line oscillation in Florida has attracted the attention of ny geologists, among whom may be mentioned Shaler, Heilprin, Dall of the earlier investigators, and Matson, Sanford, Sellards, w, and myself of the later ones. Shaw and I have recently ewed the subject.[1] That subsequent to formation of the Pleisne barrier reef of Florida, the reef tract was elevated to a height ut 50 feet above its previous stand and that this elevation was owed by submergence to an amount of about 30 feet is shown by (1 a submerged cave at Miami; (2) submerged solution well below se level, near East Bahia Honda Key;[2] (3) submerged peat bed at K West; (4) submerged indurated, cemented, recrystallized oolite er the Marquesas; (5) submerged wave-cut terrace front at Tugas.

n addition to this evidence Shaw and I say in the paper cited:

> dditional deductions of importance may be made from the submarine physiography at epths beyond 10 fathoms. Although the investigations are at present only in a pr minary stage, it may be said that along the sides of the Gulf Stream from opposite M ni to Satan and Vestal Shoals, just west of Sand Key, the Coast and Geodetic Survey ch ts indicate fairly uniform slopes from 10 to 100 fathoms, but there may be narrow te ces which are not brought out by the soundings. West of Vestal Shoal the sea bo m drops suddenly from 10 to 20 fathoms, with a flat or gently sloping surface be een 21 and 28 fathoms. South of Coalbin Rock there is an escarpment between 10 d 30 fathoms, a flat or gentle slope between 30 and 40 fathoms, and another flat or ntly sloping area between 40 and 50 fathoms. The soundings are not sufficiently nu erous to trace surfaces with a feeling of confidence, but the scarp from 10 to be een 25 and 30 fathoms is clear cut and can be followed for 25 miles to the west end of he Quicksands. Westward in the vicinity of Tortugas there are, besides, the bo m of Tortugas lagoon and the surface of the shoal 7 to 10 miles west of Loggerhead K , two undersea terrace plains, one at a depth of 15 to 17 fathoms, the other, which is large plain west of Tortugas, ranges in depth from 28 fathoms on its landward to 36 thoms on its seaward edge, and has an east and west width of 10 miles. The 15 to fathom flat is especially well developed south and southwest of Tortugas. It is

[1] ughan, T. W., and Shaw, E. W., Geologic investigations of the Florida coral-reef tract, Carnegie In Washington Yearbook No. 14, pp. 232–238, 1916.

[2] al communication of Mr. Samuel Sanford.

separated by a scarp from the 28 to 36 fathom flat, and by another scarp from
shallower levels in Tortugas. The presence of the continuous scarp from Coalbin R
to off the west end of the Quicksands, with a depth of 25 to 30 fathoms at its foot,
the presence of a terrace 28 to 36 fathoms deep, 10 miles wide, and bounded on its l

FIG. 18.—CHART OF NORTHERN END OF FLORIDIAN BARRIER REEF. FROM UNITED STATES COAST AND GEODETIC SURVEY CHART NO. 165.

ward margin by a similar scarp, suggest that the portion of the Florida reef tract east of Key West at one time stood some 20 fathoms higher than now, while the 15 18 fathom terraces suggest another, shallower stand of sea level.

Although the tracing of the oscillations of the Florida reef tract can not no be made in detail, it seems probable that it at one time stood more than 120 feet h ner

at present (and has been submerged to a similar amount). Besides the suggested er swing there have been intermediate stands of sea level and numerous minor lations. The last movement of importance was one of submergence, but subsequent to it there has been a minor uplift of some 10 feet or slightly more in the vicinity iami.

he accompanying figure (fig. 18) shows that the flat that the living rier-reef margins or above which coral-reef patches rise extends ond the northern reef limits, near Fowey Rocks. The living barreef has developed seaward of the Pleistocene barrier near the edge previously prepared platform, for the continuity of the platform spective of the presence of the reefs shows that its origin is independent of them.

CAMPECHE BANK.

he best known reef on the Campeche Bank is Alacran Reef, which described by A. Agassiz in considerable detail in 1888.[1] (See 73, photograph of model.) Heilprin in 1891[2] said regarding catan, "the evidence is all but conclusive that there has been nt subsidence"; but I am unable to discover in his article the is of this opinion. Dr. C. W. Hayes orally informed me shortly ore his deeply lamented death that there is clear evidence of nt submergence around Terminos Lake at the base of the peninon its west side. The lagoons between Progreso and Holbox nd are strongly suggestive of submergence. There is a steeper e between about 20 and 28 on the outer edge of the bank, indiing change in position of sea level by submergence, similar to the nge already recorded for St. Thomas and other West Indian nds.

this connection the following quotation from Alexander Agassiz be introduced:[3]

fact, what I have seen so far in my exploration of the coral reefs of the West Indies d show that wherever coral reefs occur, and of whatever shape, they form only a paratively thin growth upon the underlying base, and are not of great thickness. lorida they rest upon the limestones which form the basis of the great peninsula. he Yucatan Bank they are underlain by a marine limestone. In Cuba they abut the Tertiary limestones of its shore. Along Honduras, the Mosquito Coast, and orth shore of South America they grow upon extensive banks or shoals, parts of hore plateau of the adjoining continent, where they find the proper depth.

doubt if there is any one bold enough to claim that Campeche k has been formed by infilling behind a barrier reef, for it is too biously due to a large gentle flexure of the earth crust or some r kind of broad structural uplift, and that in suitable places l grows on the surface of the submarine plateau formed in the ner indicated. E. W. Shaw[4] collected a few bottom samples 6 to

[1] Agassiz, A., Three cruises of the *Blake*, vol. 1, p. 71, 1888.
[2] Heilprin, A., Geological researches in Yucatan, Phila. Acad. Nat. Sci. Proc. for 1891, p. 148.
[3] Mus. Comp. Zool. Bull., vol. 26, p. 172, 1894.
[4] Shaw, E. W., Oral communication.

8 miles off shore at Progreso, and in these he found only two fragme of coral, the main mass of the samples being shell fragments.

HONDURAN REEFS.

Although this is an important barrier reef, its length being sea-miles, I know of no adequate published description of it, nor any published account of the shore line or of the oscillations of strand line behind it. The configuration of Honduras Bay and the Gulf of Dulce, which lies inland from it and is connected wit by a waterway, as well as that of Chetumal Bay, points clearly submergence. The reef occupies the outer edge of a platform 1(22 miles wide and is separated from the shore by a channel from to 33 fathoms deep. This is a remarkably continuous barrier r but it shows discontinuity at its southern end and therefore evide of superposition.

MOSQUITO BANK.

Hayes, although he was not giving particular attention to c reefs, has made one of the finest studies of a shore line in a c reef area as yet published.[1] The following is quoted from article:[2]

7. In middle Tertiary time the region was elevated and subjected to long-conti subaerial degradation, and the narrower portion of the isthmus was reduced to a plain, with monadnocks at the divide near the axis. There is no evidence that communication has existed between the two oceans across this portion of the ist since the middle Tertiary uplift.

8. In post-Tertiary time the region was again elevated and the previously deve peneplain deeply trenched.

9. A recent slight subsidence has drowned the lower courses of the river va and the estuaries thus formed have subsequently been filled with alluvial de

J. E. Spurr furnished me a note[3] confirming Hayes's dedu regarding the submergence of the lower courses of the strean the east coast of Nicaragua. Subsequently I had profiles d across Mosquito Bank (see text fig. 11, page 275).[4] These ind submergence to an amount of about 20 fathoms. As on Mos Bank there is a submerged terrace front between about 20 a fathoms in depth, the bank had to exist previous to formati that feature, and as the living reefs grow on the shallower which according to available evidence was out of water duri least a part of Pleistocene time, they are necessarily superpos an antecedent basement. Furthermore, the enormous area flat and the relatively small areas occupied by living reefs, le the same conclusion—that is, the living reefs are merely growi parts of a submarine plateau where conditions favor their life.

[1] Hayes, C. W., Physiography and geology of region adjacent to the Nicaragua Canal route, Amer. Bull., vol. 10, pp. 285–348, pls. 30–32, 1899.

[2] Idem, p. 348.

[3] Amer. Geog. Soc. Bull., vol. 46, p. 429, 1914.

[4] Wash. Acad. Sci. Journ., vol. 6, pp. 57, 62, 1916.

he shore-line phenomena of Panama and Costa Rica have been fully described by D. F. MacDonald in his forthcoming report he physiography and geology of the Canal Zone and adjacent s. His conclusions in general accord with those I have expressed ther areas.

SOME OTHER WEST INDIAN ISLANDS.

T. Hill in 1899 [1] pointed out "that Jamaica was once a more nsive land than now, with benched and terraced margins which submerged by subsidence," and that "similar submerged s are now occupied by the growing reefs around the island." appears to hold the view that the reefs were formed during t, after submergence, and as regards the elevated fringing reefs ieve he is correct. In fact, Mr. Meinzer and I make a similar pretation of the conditions under which the coral-reef terraces iba were formed. But, it seems to me that the barrier reef off unt Point, Jamaica, has been formed after an episode of sub- ence. The pouch-shaped harbors of Jamaica suggest that derable stretches of the Jamaica shore line have undergone t submergence.

have compiled information on the shore lines of other West an islands, but to present more seems unnecessary. Possibly ot a reef off the southeast side of Barbados, all the off-shore e Indian reefs on which I have obtained information have ed on preexisting flats or plateaus during or after an episode of ergence.

BRAZIL AND ARGENTINA.

erbert M. Smith,[2] it seems, was the first to recognize evidence of ergence on the east coast of South America, and Rich [3] has a pertinent application of Smith's observations and deductions e coral-reef problem. Smith says:

> h an estuary as I have described could only have been formed by the subsidence land over a great area, and the encroachment of the sea on some former Amazons s tributaries.

uring late geologic time there is in the region of the Amazon nce of a higher followed by a lower stand on the land.

anner has made the most careful study of the shore line of l, and summarizes his conclusions as follows: [4]

> lthough no changes of level are known to have taken place within the historic ri , there are evidences of both elevation and depression of the Brazilian coast in eologic times.

M Comp. Zool. Bull., vol. 36, pp. 99, 100.

Sm h, Herbert M., Notes on the physical geography of the Amazon Valley, Amer. Naturalist, vol. p 7-37, 1885.

R , John L., The physiography of the lower Amazon Valley as evidence bearing on the coral-reef ob , Science, new ser., vol. 45, pp. 589-590, June 8, 1917.

B ner, John Casper, The stone reefs of Brazil, their geological and geographical relations, with a p on the coral reefs, Mus. Comp. Zool. Bull., vol. 44, pp. 168, 169, 1904.

9. The evidences of depression consist of:

(*a*) The open bays: Rio de Janeiro and Bahia.

(*b*) The partly choked-up bays, such as Santos and Victoria.

(*c*) The coast lakes formed by the closing of the mouths of estuaries such as Manguaba, Lagoa do Norte, Jiquia, Sinimbu, etc.

(*d*) Embayments altogether filled up.

(*e*) The islands along the coast are nearly all close in shore and have the appea of having been formed by depression of the land.

(*f*) The buried rock channels at Parahyba, now filled with mangrove swam mud, show a depression of at least twelve metres since those channels were cu

(*g*) Wind-bedded sand below tide level on Fernando de Noronba.

10. The evidences of elevation consist of:

(*a*) Elevated sea beaches especially well shown about the Bay of Bahia, an the coast of the State of Bahia.

(*b*) Marine terraces about Ilheos in the State of Bahia. These are abou metres above tide level.

(*c*) Horizontal lines of disintegration about one metre above high tide in g and gneisses at and about Victoria, State of Espirito Santo..

(*d*) Burrows of sea urchins so far above low tide that sea urchins can not n in them. These are well shown at Pedras Pretas on the coast of Pernambuco.

11. Of the two movements the depression has been much the greater and earlier.

12. The great depression probably took place in early Pliocene times.

Additional evidence in support of the submergence of the Bra coast is given by O. P. Jenkins.[1]

That the last dominant shift in the position of the strand l eastern Brazil was by submergence, it seems to me, is incontrove and that the Brazilian reefs are merely growing on the surfac submerged continental shelf is too obvious to need defense. In relations the Brazilian reefs accord with all other American of reefs, perhaps with the exception of the Barbadian reef sp mentioned on page 301. Professor Branner dates the subme whereby the Brazilian harbors were brought into being, as Pli whereas the submergence in the other areas discussed is Recent. Without definite evidence I should not be justified in the drowning a later date than that assigned to it by Professor Br but I now know that I assigned too great antiquity to some p graphic features I considered about the same time that he was e on his work on the Brazilian stone reefs; for instance, the higher terraces are Pleistocene and *not* Pliocene, as I said in the Cuba previously cited. May not the antiquity of the submergence Brazilian coast be less than Professor Branner inferred? M both the submergence and the minor uplift following it be Pleistocene in age? Should the two events mentioned be geolo Recent, the shore-line history of Brazil would parallel that of Central America.

[1] Jenkins, O. P., Geology of the region about Natal, Rio Grande do Norte, Brazil, Amer. P Proc., vol. 52, pp. 431–465, 1913.

Willis has directed attention to two areas of submergence by downrping along the Argentine coast, namely, the embayment of the o de la Plata and Bahia Blanca;[1] but Barrell is of the opinion, from e character of the submarine profiles, that there has been subrgence of the coast subsequent to the warping.[2] That there has en in late geologic time a rising of ocean level on the Argentine ast seems a justified deduction.

ATLANTIC COAST OF THE UNITED STATES NORTH OF FLORIDA.

That the last shift in position of strand line from the Georgia-orida line at least to Narraganset Bay has been by submergence is clearly shown by drowned stream mouths, resulting in estuaries d harbors, is so well known to geologists that no detailed presentan of evidence is necessary. Northward from near Boston there s been subsequent to submergence, emergence, probably due to ustal rebound after deglaciation and relief of the pressure exerted the superincumbent continental glaciers.

PES OF WEST INDIÁN AND CENTRAL AMERICAN LITTORAL AND SUBLITTORAL PROFILES AND THEIR RELATIONS TO CORAL REEFS.

In my paper on littoral and sublittoral physiographic features of e Virgin and northern Leeward islands,[3] I pointed out that there e four types of sublittoral profiles in the West Indies (see fig. 19) follows: (1) That found off volcanic islands, such as Saba, into the es of which the sea has cut relatively narrow platforms; (2) fault ne profiles, such as the north side of St. Croix; (3) wide undersea ts, where planation agencies have long been active, as off Anguilla d north of St. Thomas; (4) submarine banks, such as Saba, Pedro, d Rosalind, which have no bordering land, and whose upper surces lie between 9 and 30 fathoms below sea level. All of these eas have undergone geologically Recent submergence. Where the offshore reefs occur?

There is no barrier reef on the fault slope on the north side of . Croix. No reef started as a fringing reef, then increased in thickss and grew seaward so as to form a prism of coral-reef rock d material caught behind the reef, so as to become converted cording to the Darwinian hypothesis into a barrier reef; but there a barrier off the south side of the island, where gently dipping limeones pass below the sea and produce a platform on the surface of ich at the proper depth a barrier reef has formed. Off the fault ore of the south side of Oriente province, Cuba, there is no barrier f, but farther west, between Cape Cruz and Trinidad where there

[1] Willis, Bailey, Geologic notes, in Hrdlicka, A., Early man in South America, Bur. Amer. Ethn. Bull. pp. 16–18, 1912.

[2] Barrell, Joseph, Factors in movements of the strand line and their results in the Pleistocene and postPleistocene, Amer. Journ. Sci., ser. 4, vol. 40, p. 6, 1915.
Washington Acad. Sci. Journ., vol. 6, pp. 53–66, 1916.

is a submerged flat underlain by gently dipping limestones there offshore reefs, some of which have the barrier form. Where th are extensive offshore flats at the proper depths, if the other ecolo conditions are favorable, reef corals grow upon the surface of flats and form either patches, stacks, or barriers.

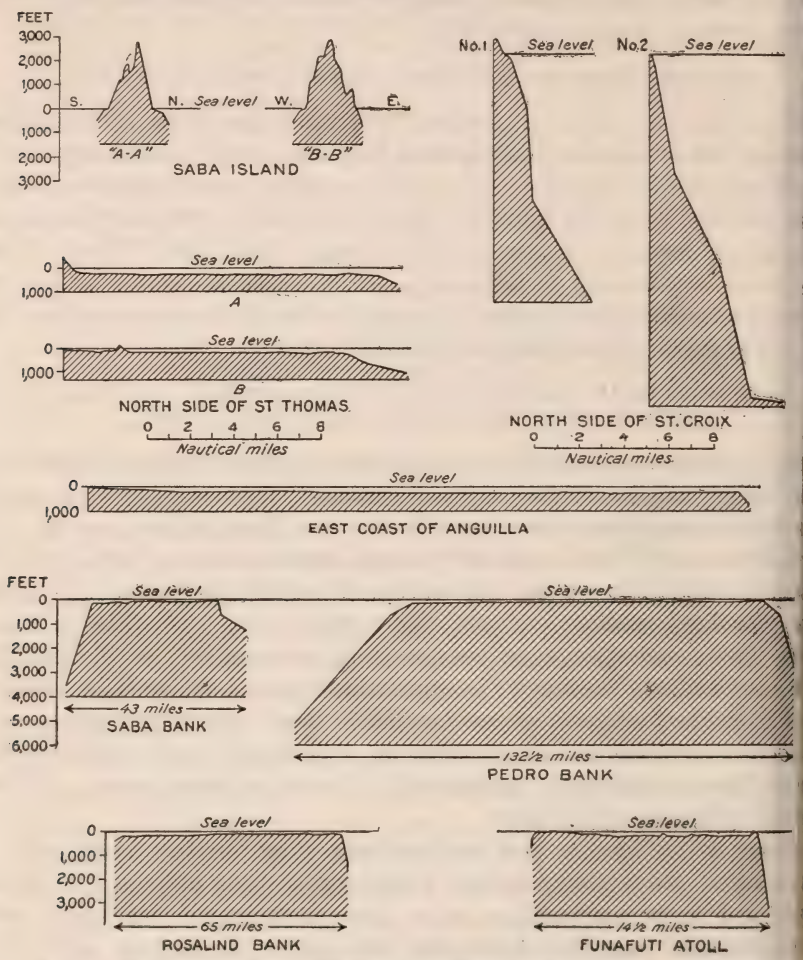


FIG. 19.—TYPES OF WEST INDIAN SUBLITTORAL PROFILES AND PROFILE OF FUNAFUTI ATOLL.

It seems that no one would try to explain Saba, Rosalind, or Pe o Bank as the result of infilling behind barrier reefs. They are sub a- rine plateaus, leveled by planation agencies, which almost certa ly were both subaerial and submarine, and they have been submerge in Recent geologic time. There is a rather meagre growth of reef co ls on their windward sides; but these banks are scientifically of g at importance, for, except that the coral growth is not so luxuri t, they essentially duplicate the great atolls in the Pacific.

ERGED BANKS NORTH OF THE CORAL REEF ZONE IN THE WESTERN ATLANTIC OCEAN.

nat there are off the Atlantic coast of Central and North America, h of the temperature zone in which coral reefs now exist, sub- ne banks at suitable depth below sea level for the growth of reef- ing corals, has been stated in several of my papers.[1] There are submarine banks projecting seaward from the eastern part of ral and North America. Named in order from the south north- l these banks are, first, three on which there are coral reefs, ely, Mosquito Bank off Nicaragua and Honduras, Campeche k off Yucatan, and the Floridian Plateau; and, second, three on h there are no coral reefs, namely, Georges Bank, the banks off the t of Nova Scotia, and the Grand Banks of Newfoundland. The ence of such banks is entirely independent of corals, but corals grow on the surface of such banks where the necessary ecologic litions prevail.

IARY OF THE CONDITIONS UNDER WHICH THE AMERICAN FOSSIL AND LIVING CORAL REEFS FORMED.

The elevated Pleistocene fringing reefs of the West Indies are rated by erosion unconformities at their bases from the geologic nations that they overlie, but they were usually, if not invariably, ned during intermittent uplift following considerable depression.

The offshore reefs, whether forming parts of more or less bedded nations or forming patches, stacks, or barriers of living reef, were ned during or after submergence, as is shown in the case of the l reefs by unconformable basal contacts wherever basal contacts d be studied, and in the case of the living reefs by a great variety vidence indicating geologically Recent submergence.

The offshore reefs grew upon or are growing upon antecedent s, only a small part of the surface of which was or is covered by s. The flats existed prior to the submergence during or after h the reefs developed. Corals are constructional geologic agents help build up the sea bottom, but the large flats on which they v would exist were there no corals. Such flats are not confined he temperature zone in which corals live.

. The submergence of the basements of the fossil reefs seems more onably explained as the result of differential crustal movement; the development of the living reefs seems in large part a result eologically Recent rise in the stand of ocean level, for nearly the re eastern shore of the Americas from Argentina on the south to e Cod on the north exhibits evidence of Recent submergence, after ch there has been in some places minor emergence by differential stal movement. The amount of the submergence usually seems

[1] ience, new ser., vol. 41, pp. 508, 509, April 2, 1915; Geol. Soc. Amer. Bull., vol. 26, pp. 58–60, 1915; Amer . Sci., ser. 4, vol. 41, p. 134, 1916; Carnegie Inst. Washington Yearbook No. 14, p. 238, 1916.

to be about 20 fathoms, but in places some facts indicate that maximum is between 30 and 40 fathoms. Although more accu investigations of the amount of the submergence are needed, available evidence accords with the hypothesis that glacial contr one of the important factors in bringing about the formatio living coral reefs.

Coral reefs of the Pacific Ocean.

It is manifestly impracticable to consider in this chapter more a few of the important reefs of the Pacific Ocean. Those sele for discussion are the Great Barrier of Australia, the barrier ree New Caledonia, and those off the Fiji and Society islands. Fi a few paragraphs will be devoted to atolls.

Great Barrier Reef of Australia.

The literature on the Great Barrier Reef is very extensive, includes contributions from numbers of investigators, among w Jukes, Saville-Kent, H. B. Guppy, Alexander Agassiz, A. C. Had Wood Jones, E. C. Andrews, C. Hedley and Griffith Taylor, E worth David, W. M. Davis, and A. G. Mayer may be mentic R. A. Daly and I have based statements regarding it upon c graphic studies. No attempt will here be made to review all literature, and attention will be mostly confined to those papers in my opinion, correctly interpret the relations of the reef.

Andrews in 1902 published a remarkable paper [1] on the shore of Queensland and the platform on which the Great Barrier stands. This paper contains an excellent account of the phy raphy of the Queensland coast, applying the deductions based the physiographic study to the conditions under which the developed, and in it is recognized the significance of a contin platform and an interrupted reef. Because of the embayed s line Andrews correctly inferred submergence of the Australian tinental shelf, and he makes the important statement:

> * * * the continuance in width of the shelf southwards of the limits of (coralline), and the great shoals thereon, points to a minor part only of the shelf formed of coral growth.[2]

A few years later Hedley and Griffith Taylor published a valu paper on the same subject.[3] They accepted Andrews's dedu

[1] Andrews, E. C., Preliminary note on the geology of the Queensland coast with references geography of the Queensland and N. S. Wales Plateau, Linn. Soc. N. S. Wales, Proc. for 1902, pt 146–185, 1902.

[2] Idem, p. 177.

[3] Hedley, C., and Taylor, T. Griffith, Coral reefs of the Great Barrier, Queensland: A study structure, life distribution, and relation to mainland physiography, Australasian Assoc. Adv. Sc laide Meeting, Jan. 1907, pp. 394–413, 3 pls. 1908.

ding submergence and devoted particular attention to the s of wind-induced currents in shaping atolls. They also say:

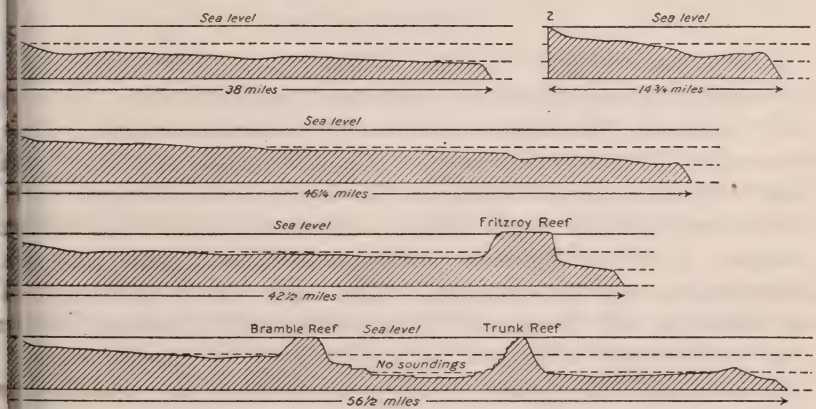
ay be allowed, though Darwin deprecated the idea, that the continental shelf ady prepared with numerous banks representing eroded islands, just reaching in the required distance of the surface, when the first coral builders came. [1]

a subsequent page they add:

tever the history of the Great Barrier Reef was, the reefs of the Coral Sea, such ou Reefs, Flinders Reefs, and Herald Cays, shared in it. [2]

ave stated in one of my papers:[3]

nspection of the admiralty charts for the eastern coast of Australia shows con-ly that the platform on which the Great Barrier Reef of Australia stands has



–PROFILES ACROSS CONTINENTAL SHELF, EAST SIDE OF AUSTRALIA. THE LATITUDE AT THE INTER-N OF EACH PROFILE WITH THE SHORE LINE IS FOLLOWED BY A STATEMENT OF THE DIRECTION OF ROFILE FROM THE SHORE.

T OF THE SOUTHERN END OF THE GREAT BARRIER REEF:
OM SHORE EAST OF LEADING HILL, S. LAT. 25° 26′ 15″, SOUTH 82° EAST.
OM BASE OF SANDY CAPE, S. LAT. 24°, 53′ 40″, NORTH 68° EAST.
OM TOOWONG HILL, S. LAT. 24° 22′ 4″, NORTH 45° EAST, PASSING BETWEEN LADY ELLIOT AND ADY MUSGROVE ISLANDS.
S THE GREAT BARRIER REEF:
OM RODD PENINSULA, S. LAT. 24° 0′ 0″, NORTH 50° EAST.
OM GEORGES POINT, HINCHINBROOK ISLAND, S. LAT. 18° 25′ 40″, NORTH 72° 30′ EAST.

tence independent of the Great Barrier Reef, and that corals have established lves on this platform where the conditions favorable for their life are realized.

Dly has given cross-sections of the Australian shelf both south of d cross the Great Barrier Reef in two of his papers,[4] and I have sted a series of cross-sections in one of mine,[5] both of us basing rofiles on the British Admiralty charts. There is one important hown by both Daly's and my profiles, but which Daly seems t o have emphasized. It is that the platform not only continues

1 reefs of the Great Barrier, Queensland, p. 406.
., p. 413.
hington Acad. Sci., Journ., vol. 4, p. 32, 1914.
R. A., The glacial-control theory of coral reefs, Amer. Acad. Arts and Sci., vol. 51, p. 197, figs. 14, 15; Problems of the Pacific Islands, Amer. Journ. Sci., ser. 4, vol. 41, p. 179, figs. 26–29, Feb. 1916.
Whington Acad. Sci. Journ., vol. 6, p. 64, profiles Nos. 1–5, 8–14, 1916.

southward from the reef limits, but in many places the barrier stands not on the margin of the shelf but miles landward from edge. (See text-fig. 20.) There is also a significant terrace fr at depths somewhat deeper than 120 feet. These profiles sho be compared with those for the West Indies (fig. 11, p. 275). T tell essentially the same story. The platform can not be due to presence of the Great Barrier Reef, for in many places it proj beyond the reef. I state in my paper cited:

> The evidence in favor of a shore line between 25 and 30 fathoms below presen level is strong, if not conclusive, and supports the deduction that the living b reef is growing on what was a land surface in Pleistocene time, an interpret essentially that proposed by E. C. Andrews in 1902.[1]

NEW CALEDONIA.

I have seen no good account of the coast of New Caledonia whose shores is one of the most important barriers known. Accor to P. Marshall, [2] "the northeast coast is practically straight, but n inlets that form excellent harbours penetrate the southwest coa The chart shows indentations in the north coast, although they not so deep as those on the south. I find references to the shore features in two of Professor Davis's papers,[3] and from them cer information may be obtained. The shore line is embayed, t are deltas mostly contained in the embayments between headl that are strongly cliffed on the sea front. The present barrier has developed subsequent to the truncation of the headlands subsequent to the submergence that has caused the embay of the coast. Just how much of the platform surmounted by

[1] W. M. Davis has published since the manuscript of this paper went to press an article entitle Great Barrier Reef of Australia (Amer. Journ. Sci., vol. 44, pp. 339-350, Nov., 1917), in which he c me and others because we have not "satisfactorily explained" the origin of the form of "the con mass." Among the statements of Professor Davis is "Vaughan's view is based on the physio investigations of parts of the eastern coast of Australia by Andrews (1903); * * *", after he h duced two quotations from my paper on the littoral and sublittoral physiographic features of the Islands, etc., as given in abstract (Amer. Geolog. Soc. Bull., vol. 27, pp. 41–45, 1916). Professo has drawn an erroneous deduction regarding my cartographic studies of the Great Barrier Reef could not have been based on Andrew's work, because Andrews neither published nor made c on a series of profiles across the Australian platform, such as those I had prepared. Furtherm emphasis of the fact, which it seems I was the first to point out—namely, that the present Great Reef in places stands some miles landward from the margin of the continental shelf—and my de therefrom, that the platform can not be attributed to infilling behind the reef, do not warrant the i that "Vaughan * * * has excluded coral-reef agencies from any part in forming the platfor * * *." I not only do not know how the Australian continental shelf was formed, but I do n how any one of a number of hypothesis can be tested. I, therefore, endeavored to confine my di to matters on which evidence is procurable, and said nothing regarding the origin of the pl Professor Davis advances the hypothesis that the platform on which the present Great Barrier is is a "mature reef-plain", formed in a previous physiographic cycle, and that it has been recen merged. Whether reefs in past geologic time formed a rampart on the edge of the Australian con shelf and a plain resulted from infilling behind the barrier can at present be neither proved nor di and on this subject I have expressed no opinion.

[2] "Oceania," Handb. regionalen Geologie, vol. 7, Abt. 2, p. 23, 1912.

[3] Davis, W. M., Shaler Memorial study of coral reefs, Amer. Journ. Sci., ser. 4, vol 40, pp. 232, 243, 245, 270, 1915; Problems associated with the study of corals, The Scientific Monthly, vol. 2, fig. 25, p. 27, 1916.

edonian barrier is due to the cut and fill process of marine
nation at and below sea level during the cliffing of the
montories and to the sediment deposited in the sea, derived
ough the erosion of mature valleys, I can not say with cer-
ty, but that so much material deposited in the sea would
er the influence of waves and currents form a submarine plain
warranted deduction; and as the barrier reef is crossed by
s and is discontinuous at both the southeast and northwest ends,
deduction seems safe that it is superposed on a submerged plat-
n of antecedent existence.

FIJI ISLANDS.

hat the barrier reefs off the Fiji Islands have developed during
fter submergence of their basements is obvious from an inspec-
of the charts to anyone familiar with the physiography of shore
s. The numerous reproductions of British Admiralty charts in
Agassiz's volume on the Fiji Islands[1] is valuable and convenient
such a cartographic study. That the indentations of the shore line
ne Fijis are due to the drowning of the lower parts of subaerially
ned valleys has been pointed out by many geologists, the first
hom appears to have been Dana, who says:[2]

ere is, further, not merely probable but positive evidence of subsidence in the
coast indentations of the high islands within the great barriers. The long points
deep fiordlike bays are such as exist only where a land, after having been deeply
d by erosion, has become half submerged. The author was led to appreciate
vidence when on the ascent of Mount Aoraion Tahiti, in September of 1839.
to any level above that of five hundred feet the erosion valleys of Tahiti would
ne deep bays, and above that of one thousand feet, fiordlike bays, with the
s spreading in the water like spider's legs; and this is a common feature of the
ls and islets within the lagoons of barrier islands. The evidence of subsidence
ts of no doubt. It makes the conclusion from the Gambier group positive;
equally so that for Raiatea and Bolabola represented on the charts in Darwin's
l Islands;" the Exploring Isles and others of the Fiji group; and that for islands,
and small, in the Louisade Archipelago and in other similar groups over the
e.

is statement was misinterpreted by Davis as being confirmation
arwin's theory of coral reefs,[3] which, as is more than once pointed
in the present paper (see especially p. 249), carries with sub-
gence an hypothesis of platform building. Evidence of sub-
ice does not prove that the flat lying between a barrier reef
the shore has been formed by infilling behind the barrier.
ly made a definite statement in 1910 in a list of "maximum
hs recorded for the drowned portion of these valleys," in which

[1] ssiz, Alexander, The Islands and Coral Reefs of Fiji, Mus. Comp. Zool. Bull., vol. 33, pp. 167, 112 1899.
[2] a, J. D., Corals and coral islands, ed. 3, pp. 273, 274, 1890.
[3] s, W. M., Dana's confirmation of Darwin's theory of coral reefs, Amer. Journ. Sci., ser. 4, vol. 35, -188, Feb. 1913.

he includes Mbengha and Moala of the Fiji group.[1] Subsequen Davis, in several of his papers, cited and others have similarly int preted the estuarine character of the lower ends of the valleys

Were the platforms on which the Fijian reefs stand, or which th margin, formed by infilling behind barriers or are the reefs mer superposed on antecedent platforms? In 1914 I published following statement:

> Having presented criteria for recognizing the relations of continental and i insular platforms supporting barrier reefs to the presence of the reefs, islands suc those in the Society and Fiji groups may be considered. * * * A study of charts of barrier reef islands, as Viti Levu, Fijis, and Tahiti, Society Islands, sh that the platforms are independent of the presence of reefs, and therefore the r tions in these islands are similar to those indicated for barriers off continental sho for here the reefs are also superimposed on platforms antedating their presence.

Plate 7 of Agassiz's work on the Fiji Islands, already cited, sho the continuity of the platform northward and westward from Ova without any margining barrier reef. In my opinion these relati clearly show that the reef, where it is present, is merely superpo on an antecedent platform, and that the suggestion of Davis, t the entire platform is due to infilling behind a reef which in pla has ceased to grow, is farfetched.

Recently E. C. Andrews and W. G. Foye have published imp tant papers on the Fijis. Andrews in his paper says:

> The Viti Levu salt water arms, therefore, with their contained deltas, suggest r submergence of the Viti Levu coastal lowland in recent time, with the conseq n drowning of the lower portions of the river courses.
>
> The island is girt with a Great Barrier Reef, several hundreds of miles in len h, broken here and there by passages. The present Great Barrier Reef, which ris to the level of the sea, has thus, in all probability, been built up by coral-reef organ m upon the submerged lowlands of Viti Levu.[2]

Andrews similarly interprets the conditions of development of re barrier reef off Vanua Levu. The interpretations advanced y Andrews essentially accords with mine; that is, the reefs are su r- posed on a depressed platform that was previous to its submerge e a coastal lowland.

Foye [3] makes the following statement regarding Viti Levu:

> In general the present coral reefs are developing on platforms which origin ed during the deposition of the coastal series.[4]

Regarding Vanua Levu he says:

> I visited only the eastern and central portions of Vanua Levu. The modern fri ng reefs are here developing either along the shore line of recently submerged vol ic rocks or on coastal flats formed of the fine ash swept from the elevated hills of b-

[1] Daly, R. A., Pleistocene glaciation and the coral reef problem, Amer. Journ. Sci., ser. 4, vol. 30, 06, November, 1910.

[2] Andrews, E. C., Relations of coral reefs to crust movements in the Fiji Islands, Amer. Journ ci., ser. 4, vol. 41, p. 138, 1916.

[3] Foye, W. G., The geology of the Fiji Islands, Acad. Nat. Sci. Proc., vol. 3, pp. 305–310, April, 19

[4] Idem. p. 306.

ıe tuffs. The most recent movements have been differential, and while uplift aken place at the southeastern side of the island, subsidence has occurred to the and north. The modern barrier reef occurs where subsidence has taken place r due to tilting or faulting during uplift.[1]

ncerning the Lau Islands, he states:

thin quite recent times the islands have subsided 50 to 90 feet and the modern reefs are developing on the eroded and submerged platforms.[2]

ıe paragraph of Foye's conclusions is as follows:

e data assembled by Daly and Vaughan convince the writer that Pleistocene rms exist very generally throughout the coral seas. Yet while this is true, the rms in Fiji are post-Pleistocene in their development. The writer was unable cover any evidence of Pleistocene wave-cut platforms.[3]

ıe second one of Foye's papers[4] contains the following signifi- statement:

re is another method by which atolls develop. The limestone islands are rapidly l to sea level by atmospheric solution. Evidence of this process may be seen diminishing limestone masses within the lagoons of many of the Lau islands. dal scour and wave action platforms are developed slightly below sea level. ples of such platforms may be seen about Fulanga and Ongea. It is significant, er, that most of these islands have lagoons 10 to 15 fathoms in depth. Such s can not be ascribed to erosion, but must be the result of recent submer- * * *

e information bearing on the Fijis may be summarized as fol-

The fringing reefs have unconformable basal contacts, as do of the West Indies.

The barrier reefs are superposed on antecedent platforms of se origin during or after submergence.

The submergence is concomitant with, if not actually due to, ential crustal movement.

In that they were formed during or after submergence and are posed on antecedent platforms, the offshore reefs of the Fijis d with all others, perhaps except a Barbadian reef, so far dered.

SOCIETY ISLANDS.

TAHITI.

Tat Tahiti had undergone subsidence is implied in statements by an,[5] the occasional harbors being mentioned in two places in his ok W. M. Davis says:[6]

The cliff-rimmed island of Tahiti, the largest and youngest of the group, has suffered ed ite subsidence after its cliffs were cut, but its bays are now nearly all filled ith elta plains; hence a pause or stillstand has followed its latest sinking.

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1 The geology of the Fiji Islands, Acad. Nat. Sci. Proc., p. 308, April, 1917.
2 Id., p. 309.
3 Id., p. 309, 310.
4 Foye, W. G., The geology of the Lau Islands, Amer. Journ. Sci., ser. 4, vol. 43, pp. 343–350, May, 1917.
5 Coral reefs and coral islands, ed. 3, pp. 149, 158, 246, 247, 1890.
6 Am. Journ. Sci., ser. 4, vol. 40, p. 271, 1915.

The condition of the reef between Taunoa Pass and Point V is interesting in this connection. Alexander Agassiz has giv good description of this part of the reef and reef platform and reproduced the British Admiralty chart of it.[1] Agassiz says:

Reef patches, the remnants of a former barrier reef, extend westward from Point parallel with the shore of Matavai Bay, forming the chain of Toa Tea ree they are merely patches of Nullipores, with here and there diminutive coral which have taken no part in the building of these reefs.

There is along the Toa Tea Reefs a great break in the continui the reef, but the platform continues, irrespective of the presen absence of a margining barrier. The depths in Matavai Bay, 16 fathoms, seem to be the maximum, are about the same as in Pa Harbor, outside which there is a well-developed reef crosse Papiete Pass. These reefs, also, seem to me to have grown u connectedly on a submerged coastal flat.

SMALLER ISLANDS OF THE SOCIETY GROUP.

Alexander Agassiz has described each of these islands in his o reefs of the Tropical Pacific,[2] and P. Marshall has made the obs tions and deductions recorded in the following quotation:[3]

This reef marks the edge of the platform of marine erosion as described by A but the original margin of the land before depression as described by Darw Dana. * * *

It is evident that if the coral reef rises on the edge of a platform of marine this very erosion would have worn the spurs back in such a way that they terminate in steep cliffs. In no instance at Huaheine, Raiatea, or Tahiti t author observed, did the spurs have an abrupt termination. The lower slope islands are in all cases notably less steep than the upper slopes.

The deep inlets that intersect the coast line of Huaheine, Tahaa, and Rai clearly due to stream erosion. Prolonged marine action would have shall filled them up or at least would have built up bars of coastal débris across the en

The author is therefore strongly of opinion that the absence of cliffs at the t tion of radiating spurs, the presence of deep water in the lagoon, and of far-r inlets, prove that marine erosion has not had any influence on the form of thes at the present sea level. * * *

Finally the deep inlets appear to be drowned stream valleys and thei strongly supports the belief that they have been subjected to an important m of subsidence.

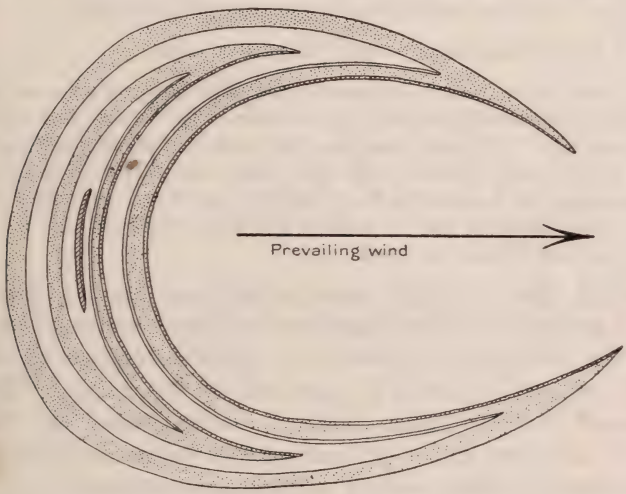
Mehetia is interesting in that it is a young volcanic island, th strongly cliffed shore, a very narrow or no platform, and no reefs around it, only a few coral patches. That the other i Murea, Huaheine, Raiatea, Tahaa, Bora-Bora, and Maupit ha undergone geologically Recent submergence and that the barri have developed during or after submergence, can not be contro Is the reef flat due to marine planation and to terrigenous sed

[1] Agassiz, Alexander, The coral reefs of the Tropical Pacific, Mus. Comp. Zool. Mem., vol. 2 154, pl. 209, 1903.

[2] Idem, pp. 140, 141, 156–167.

[3] Marshall, P., Oceania, Handb. regionalen Geologie, vol. 7, Abt. 2, p. 13, 1912.

ried by the streams to the sea prior to the submergence after ich the living reefs have formed? Unless sediment was delivered the sea so rapidly that a coastal plain pushed forward beyond the erstream divides as to protect them from attack by the sea, their ward ends should have been cliffed, should the flat have been med in the manner suggested. What are the submarine profiles the spur ends? Are there submerged cliffs at the divide tips? e of Agassiz's illustrations[1] represents a cliff of considerable height one place on the shore of Maupiti. In my opinion sufficient evi- ice is not available to establish how the reef flats of these islands re formed, and they may be made to accord with whatever theory reef-flat formation an author may prefer. Should it ultimately proved that these barrier reefs accord with the Darwinian hypothe-



1.—DIAGRAM TO SHOW HOW A LINEAR REEF LYING ACROSS THE WIND IS FORMED INTO A HORSESHOE. (AFTER HEDLEY AND GRIFFITH TAYLOR.)

a few instances in which that hypothesis applies will have been overed.

ATOLLS.

here are two kinds of atolls: Those of the first kind rise above tively shoal-water platforms, and are represented by the atolls of Great Barrier Reef of Australia, those of the Floridian reef-tract, the *faros* of the Maldives. That there was never any central land for these atolls is perfectly obvious. Hedley and Griffith Taylor, heir paper, cited on pages 245, 251, have shown how the atolls g the Great Barrier have been shaped by the prevalent, mostly l-induced, currents; and I have shown in my papers on the Mar- sas and Tortugas atolls that precisely the same principles apply em. The principles involved are illustrated by the accompany-

[1] The Coral Reefs of the Tropical Pacific, pl. 104, fig. 4.

ing diagram (fig. 21), which is copied from Hedley and Griffith Tay
Stanley Gardiner has given good descriptions of the faros of the M
dives.[1] He says in a footnote on the page referred to:

The technical term *atoll* is derived from the Maldivan *atolu*, signifying a prov
for governmental purposes. There are 13 of these in the Maldives, and many co
of the islands on separate banks, most of which have distinct encircling series of
reaching the surface. Many of the individual reefs are themselves ring-shaped
pools of water several fathoms deep in their centers. There are obvious disadvant
in using diminutives of the terms *atoll* and *lagoon* as applying to such. They
situated on shallow banks, and many are actually larger than some of the isolated
shaped reefs of the Pacific, which arise separately in the deep basin of that ocean
therefore propose to borrow further the Maldivan terms, *faro* and *velu*, the fo
signifying such a small ring-shaped reef of an atoll or bank and the latter its ce
basin. I, further, following the Maldivan use of the term *velu*, apply it to deep
even in the long, linear, circumscribing reefs of many of the banks, as I conceive
such pools have in all these reefs on banks the same mode of origin.

On page 171 of the same work, Gardiner says:

Each large reef on the bank is a separate entity that has grown up and pursue
history by itself, influenced it is true by the reefs in its vicinity but never dir
connected with them. It is only now that the bank is at all approaching the c
tion of the perfect atoll. Having seen how small faro may be formed from
earliest beginnings, we now see in North Mahlos the further fortune of such a
their joining together where possible to form long linear reefs with the loss perha
the whole inner part of their own reefs.

The second kind of atolls more or less margin and more or
completely encircle the flat summits of eminences rising from oce
depths. The Darwinian explanation of the formation of such
rings is illustrated by figure 5, page 242, of this paper. Have t
atolls formed in accordance with the postulates of the Darwi
hypothesis, or have more or less perfect rings developed on
edges of submarine flats, with or without submergence?

The origin of the first kind of atolls has been ascertained wi
high degree of probability that it amounts to certainty. They
been formed on relatively shoal submarine flats, during or follo
submergence, and have been shaped by the prevalent curr
But a basement platform for the second kind of atolls can n
traced beyond the atoll limits, at least in our present state of k
edge. However, in case of atolls of an area so large as Rangir
the Paumotus, for instance, the presumption is against their d
tion from barrier reefs according to the Darwinian hypot
They are too large, and, as Wharton long ago pointed out,
bottoms are too nearly level. If the Darwinian explanation
true, lagoon floors should be concave, more or less bowl sh
That small, flat, summit areas may result from subaerial degrad
and marine planation is known in many instances. That vo

[1] Gardiner, J. Stanley, The fauna and geography of the Maldive and Laccadive Archipelago
pt. 2, p. 155, 1901–1903.

FIG. 22.—CHART OF SALT KEY BANK. FROM U. S. COAST AND GEODETIC SURVEY CHART NO. 15.

piles may be cut to wave base is known, and on page 311 of this pa
Foye is quoted on a process by means of which reduction of limest
masses to sea level or slightly below sea level is accomplished.

In this connection Salt Key Bank, which lies between the Strait
Florida, Santaren Channel, and Nicholas Channel (text-fig. 22)
interesting, as it is 61 nautical miles long by 37 nautical miles w
Except a few marginal islets and elongate keys, it ranges betw
3½ and 8 fathoms in depth. Alexander Agassiz visited and descri
this bank [1] and says that it is composed of eolian rock similar to

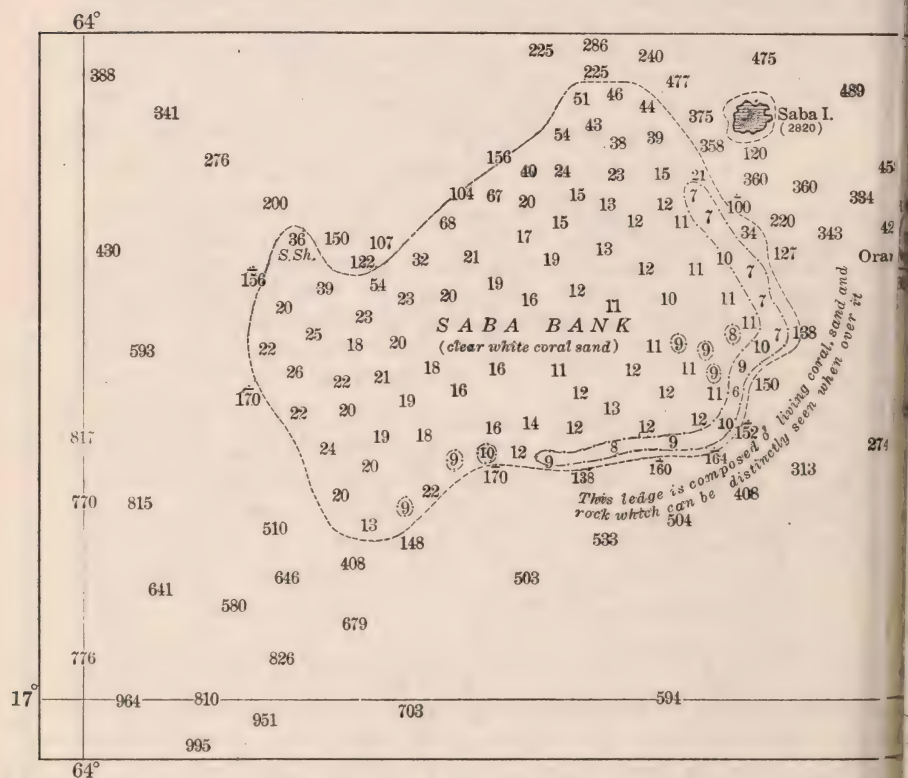


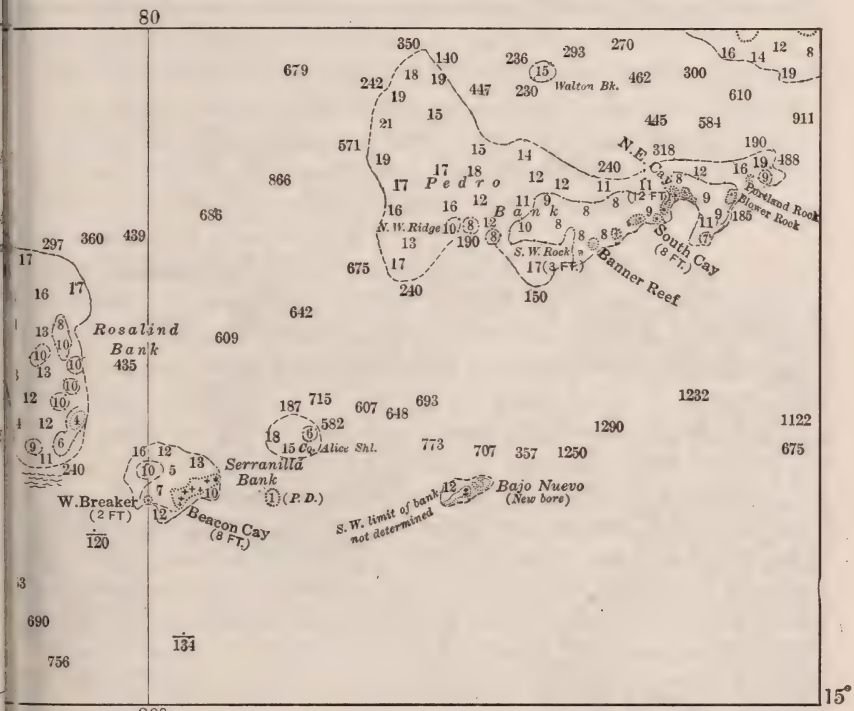
FIG. 23.—CHART OF SAN SABA BANK. FROM U. S. HYDROGRAPHIC CHART NO. 2318.

Bahamas. The bank looks as if it were once a part of the Bah
and was dissevered by faulting between it and the Bah
Whether that suggestion is or is not true, there is here a large
bank, obviously not formed according to the Darwinian hypot
that might serve an atoll foundation. Saba, Pedro, and Ros
banks in the Caribbean Sea have been mentioned on pages 303
Figures 23–25 illustrate them.

It is not practicable to work out the geology of the foundati
the Paumotuan and the Maldive and Laccadive stolls, bu

[1] A reconnaissance of the Bahamas, etc., Mus. Comp. Zool. Bull., vol. 26, p. 81, pls. 1 and 31, 1

ability seems distinctly in favor of their being submerged pla- surfaces, upon which coral reefs, mostly marginal, have estab- d themselves during and subsequent to moderate submergence. will revert to Admiral Wharton's emphasis of the levelness of floors of atoll lagoons (depth 24 to 26 fathoms), to his statement, ide the low rim of growing coral which encircles their edges in ous degrees," and to his question "What causes this remarkable larity of depth and this extraordinarily even surface over these banks?" As I believe this short article by Admiral Wharton e of the truly great contributions to our knowledge of coral reefs,



4.—Chart of Pedro Bank. From U. S. hydrographic chart No. 1290. Scale 1 inch = 48 nautical miles.

emptation to quote all of it is great. In it he points out one of undamental defects of the Darwinian hypothesis, namely, that agoon floor is not basin shaped as it should be if the atoll is due e upgrowth of a reef that began on the slopes of a volcanic cone. says: "I have no hesitation in saying that a flat floor is an riable characteristic of a large atoll, and I can not find his 'deeply ave surface' in any large atoll. On the contrary, a flat surface nd in all of these, whether the rim be above or below the surface." ly in his two papers cited has made an elaborate study of the hs of atoll lagoons of the Pacific and Indian oceans and has com- d the depths in them with the depths in the lagoon channels of same region. As the data compiled by him can not be repeated

here, his later discussion in his paper on the Glacial-control th may be consulted.[1] Daly says:

"Since probably not more than 5 m. to 25 m. can be allowed for the thickn the post-glacial calcareous veneer in the wider lagoons, the accordance of pla depth for the wider lagoons and reefless banks seems clear. Their range of 60- represents magnitudes of the same order as the depths computed for the Pleist wave-formed benches."

I have pointed out the similarity in the depths on Saba, P and Rosalind banks, to those on the atoll-lagoon floors of the P and Indian oceans—that is, the depths are between 20 and 30 fath

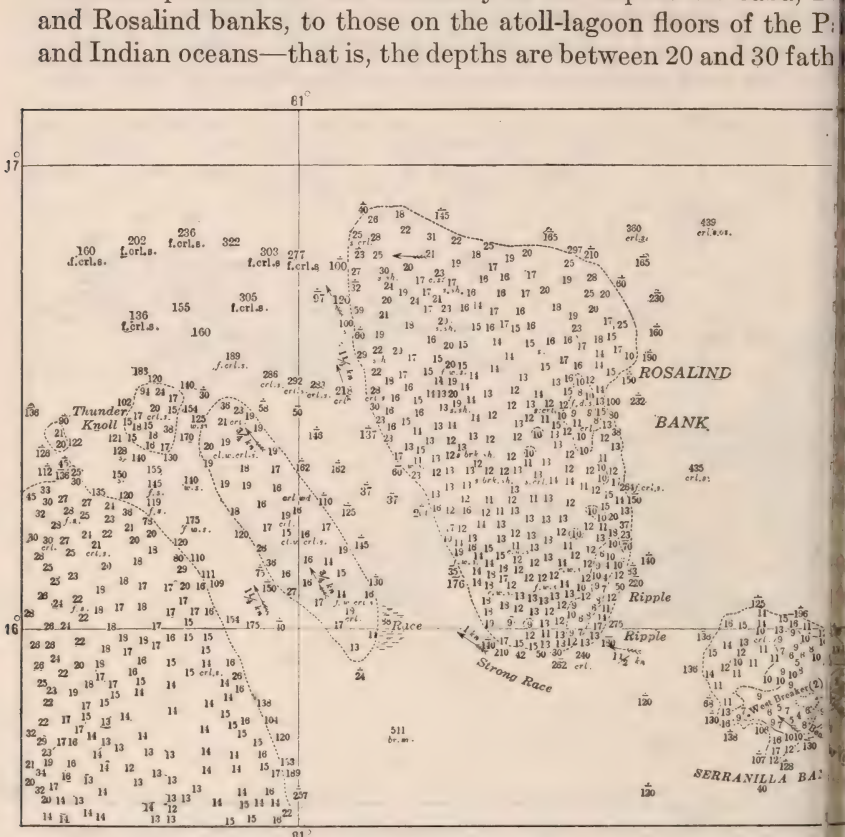


FIG. 25.—CHART OF ROSALIND AND SARRANILLA BANKS. FROM U. S. HYDROGRAPHIC CHART N 304.

The possibility of the formation of atoll lagoons by subr ri solution was eliminated in the discussion on page 250 of this pe Atoll rims are formed by constructional processes. That the g at abundance and luxuriance of reef-forming organisms on the peph ries of atolls is due mostly, if not solely, to the intolerance of suc organisms to sediment, is shown by certain of my experimen the colonies are protected from sediment, the growth of corals thi a lagoon may exceed that of corals on the outside.

It is my belief that the coral reefs forming atoll rims are supe ose on platforms that antedate the formation of the living reef an which have undergone a moderate submergence in Recent ge ogi

[1] Amer. Acad. Arts and Sci., vol. 51, pp. 178-199, 1915.

ue. It is reasonable to ascribe this submergence to rise in ocean el because of deglaciation, because the order of magnitude of the mergence is the same as the order of magnitude expected from glaciation. Marginal wave-cut benches should exist, or should ve existed around the atoll banks. Perhaps more accurate hydro- phic surveys and more detailed studies of the submarine profiles l discover them.

Conclusions.

The results of an examination of the Tertiary, Pleistocene, and ing coral reefs and reef corals of the West Indies, Central America, l the Southeastern United States are as follows:

1. The fringing reefs have formed usually, if not invariably, during iods of intermittent uplift, following considerable submergence.

2. All the important offshore reefs, both fossil and living, possibly cept the reefs off the southeast coast of Barbados, have devel- ed during or following submergence after the subaerial erosion of ir basements.

3. Most of the fossil offshore reefs, all of those on which informa- n has been obtained, and all of these living reefs are superposed on tecedent flattish basements or platforms. Where there are no tforms, as off fault shore lines and young volcanic islands, there no offshore reefs.

4. Although corals are constructional geologic agents, they are ordinate to other limestone forming agencies, and none of the erican platforms were formed by infilling behind a barrier.

5. Submarine flats and plateaus at proper depths below sea level have furnished basements for offshore reefs are not confined to e temperature zone suitable for coral growth. Such extralimital nks are Georges Bank, the banks off the coast of Nova Scotia, and e Grand Banks of Newfoundland. Reefs form on such banks ere the proper ecologic conditions for the life of reef building als prevail.

6. The submergences during and after which the fossil reefs were med were almost certainly due to differential crustal movement; e submergence of the basement of the living reefs is probably due complex causes, for there was differential crustal movement in e area under consideration during Pleistocene time, also at some ces within it during Recent time, and, in addition to these more less local movements, there seems to have been during Recent ne a general submergence of the eastern coast of America from gentina to New England. The amount of the general Recent sub- rgence lies between 40 and slightly more than 20 fathoms; an ount of the order of magnitude that would be expected to result m the effect of deglaciation in raising sea level. The principal ve-formed Pleistocene plain now lies between 26 and 36 fathoms

in depth, and is separated by an escarpment from a shallower pl
that now ranges between 17 and 20 fathoms in depth. What app
to be marginal hanging valleys north of St. Thomas and on the
Martin Plateau, and solution wells, in the Bahamas, 33 to 38 fath
deep, suggest that there may have been a short stand of sea l
about 40 fathoms below its present stand.

7. The fact that the terrace flat between 17 and 20 fathoms
depth is cut away on promontory tips on the windward side of
Thomas, while it is preserved in protected areas, indicates that
higher flat is older than the lower, and that it has been resubmer
after the development of the lower flat. The general similarity
the submarine profiles off Antigua, on the St. Martin Plateau, and
Mosquito Bank favors the inference that there was in those are
similar lowering and subsequent rise of sea level. The submer
channel within the channel at the mouth of Habana Harbor,
similar phenomena at other localities around the Cuban coast, sh
that during later Pleistocene time Cuba stood more than 100
higher than immediately previous to the cutting of these val
within older valleys, and that after the valleys-within-valleys v
formed there was submergence to an amount of about 100 feet.
of sea level during Pleistocene time and rise during Recent tim
indicated for the Bermudas, the Bahamas, Florida, Central Ame
and the mouth of the Amazon, as well as for the areas just mentio
These phenomena are in essential accord with the demands of
Glacial-control hypothesis.

8. The principal living West Indian and Central American reefs
superposed on submarine flats or plateaus of *pre-Pleistocene* age,
were dry-land areas during at least a part of Pleistocene time,
while they were dry land they were wave cut and remodeled aro
their margins by submarine planation.

9. There are two kinds of atolls, namely, (*a*) those that rise ab
relatively shoal-water platforms and were shaped by the preva
currents, which are largely wind induced; (*b*) those that more or
completely encircle the flat summits of eminences that rise f
ocean depths. These rings are formed by constructional geol
agencies, because, as submarine solution by sea water in such a
and at such depths is chemically impossible, a lower, flat area,
rounded by a higher rim can not be formed by submarine solu
or by any other known destructional agencies. The depths on
banks as Saba, Pedro, Rosalind, etc., indicate that they wer
large part, at least, above water during part of Pleistocene t
and that the flat summits are largely due to processes operativ
pre-Pleistocene time. What the processes were that caused h
leveling of the summits is a matter of pure speculation, but it s
probable that they were subaerial erosion and submarine plana

living coral rims on the banks enumerated have formed during subsequent to Recent submergence.

review of the conditions under which the principal barrier reefs he Pacific Ocean were formed leads to essentially identical conions. Those of the Australian Great Barrier, of New Caleia, the Fiji Islands, and Tahiti are superposed on antecedent forms that have been submerged in Recent geologic time. The mergence of the Australian continental shelf apparently can be gned to Recent rise of sea level because of deglaciation, as it ns that most of the surface of the platform was exposed as a dryl area by withdrawal of water from the ocean during at least a t of Pleistocene time. The submergence of the Fijian platforms oncomitant with, if not entirely due to, differential crustal movent. The superposition of the barrier reefs off the shores of the ller Society Islands on antecedent platforms is not proved. dence sufficient for the basis of an opinion is not available. The ence of reefs around Mehetia, where there is no shore platform, ignificant. That the barriers off the other smaller islands were ned after the submergence of their basements is clear. The small 's at the spurs ends, in my opinion, do not constitute evidence inst the presence of shore platforms, flats, or lowlands, antecent to submergence. That ocean level in the Indo-Pacific, ause of deglaciation, in Recent time has risen to an amount of ut 60 meters (about 33 fathoms) as postulated by Humphreys l Daly, and that this rise of ocean level had influenced the elopment of living coral reefs, is, I believe, so well established to be almost if not quite incontrovertible.

The rims of the large atolls, and perhaps of the smaller ones also, growing, in my opinion, on the surfaces of, mostly the edges of, summit areas that have undergone geologically Recent submergce. These flats, I believe, were mostly formed in *pre-Pleisto*e time, and it is my opinion that they were largely out of water, were very near the surface of the water, during Pleistocene time. hey projected above the water for an appreciable time, they should e been wave cut around their edges by the lowered Pleistocene , and evidence of such benching should be sought. I believe the dence will not be found on the hydrographic charts at present ilable, for the object of the published charts is to guide navigators her than to serve as a basis for physiographic studies of the sea ttom in depths where navigation is safe.

From what precedes I believe it is clear that I consider that there two factors that determine the vigorous development of offshore fs, which under the most favorable conditions form barriers or ll rims, the other proper ecologic conditions also being present. e first factor is the existence of an offshore flat, which may have

a land area on one side and open ocean on the other or which r
be the top of an oceanic eminence. The second factor is gradual s
mergence. The vigor of offshore reefs where these conditions p
vail can be correlated with certain ecologic demands of reef-form
corals.

Reef corals thrive on offshore flats, near or against ocean wa
because they are there removed from the deleterious eff
of both land-derived and other sediment. Some of these r
tions are well exemplified in the barrier reef off the east side
Andros Island, Bahamas. This reef grows on the outer, windw
edge of a small shallow flat, against the deep water of the Tongu
the Ocean. As the winds set landward across the reef no oce
or land-derived sediment is deposited on the reef, it is bathed
the purest ocean water, and receives the largest amount of ani
plankton that that part of the sea can supply. On the great sh
of the Bahama Banks and in the shoal waters of Florida behind
reefs the winds stir up the mud on the bottom; the sediment w
in suspension kills the plankton; when it settles it kills those bott
living organisms that can not endure being covered by mud. On s
flats reef-forming corals can not live. On shallow banks c
reefs therefore thrive best on the windward sides. However, if
flat extends far enough offshore for land-derived sediment no
reach the reef and if the depth is sufficient for waves under ordi
conditions not to stir up the mud on the bottom, but not too d
for the growth of reef corals, barriers may develop on the leew
sides of islands. A land area to the windward may actu
favor coral growth, as it breaks the force of the winds. A posi
on an offshore flat, particularly on the windward edge of a
insures a supply of the purest ocean water and an abundanc
animal plankton.

The gradual submergence of an offshore flat perpetuates the fa
able conditions for the life of reef-building corals, and gives
opportunity for continual growth upward. With upward gr
during slow submergence of the basement the ecologic condit
for the life of reef-forming corals are made better, for the delete
effects of sediment are minimized.

As regards the life of corals, the method of bringing about t
conditions is of no importance. Whether the flat was form
marine planation, by alluviation and the building of a coastal
by base-leveling through subaerial erosion, by the formation
submarine plain of deposition, or by any other special proce
unimportant, provided the flat be formed. Whether the subm
ence be caused by differential crustal movement, local or remot
by rise in ocean level due to the melting of glaciers, is u
portant, provided there be gradual submergence of the base

manner of producing the result is subordinate to the result. Whatever the conditions may be brought about, preexistent flats and gradual submergence are two factors needed to supply continuously favorable conditions for the growth of reef-forming corals. The importance of deglaciation on modern coral-reef development consists in its having caused a gradual and moderate increase in the depth of the ocean, thereby producing submergence both in rate and amount favorable for the growth of reef-forming corals.

The general conclusions here expressed are similar to those previously published in a number of my papers. Before discussing the bearing of my conclusions regarding the formation of coral reefs on the theories advanced by others, I will give brief attention to some remarks by Prof. W. M. Davis. The following paragraph is copied from a paper by him entitled: The origin of coral reefs.[1] Similar remarks occur in others of his papers.

> Reefs and Reef-Platforms. A modification of Darwin's theory has lately been proposed by Vaughan, who regards recent submergence proved by the embayments of the central islands as the determining cause for the upgrowth of existing barrier reefs but who interprets the deeper and larger part of the entire reef mass as an independent "platform" of earlier origin. As this investigator has not yet published his views regarding the origin of the reef-platforms his modification of Darwin's theory will not be here discussed further than to note that it seems inapplicable to many barrier reefs in the Fiji and Society groups; that the discontinuity of certain barrier reefs seems to be explicable on the assumption of imperfect upgrowth during and after recent and rapid subsidence as well as on the assumption of independent origins for the reefs and their platforms; and that, while the extension of reef-platforms outside the coral zone as in the case of the Great Barrier reef of Australia, truly suggests a distinct origin of reef masses, this does not exclude the contemporaneous growth of platform and reef within the coral zone during long-continued but irregular or intermittent subsidence.

Most of the objections raised by Professor Davis have been answered on preceding pages of this paper. It will be obvious to those who have read what I have said that my inferences as to submergence are by no means confined to the evidence of embayments in shore lines. In fact, many submerged areas show no clear-cut shore-line embayments. It will also be obvious that the interpretation I am making did not originate with me. E. C. Andrews, in 1902, after his work on the Great Barrier reef of Australia, put forward in essential principles the same explanation.

In answer to Professor Davis's statement "regarding the origin of the reef platform," I will say that the recognition of the fact of superposition does not require knowledge of the constitution or origin of the basement on which an object or structure has been superposed. We may recognize the fact that a book lies on a table without knowing the kind of material of which the table is composed or the process of its

[1] Nat. Acad. Sci. Proc., vol. 1, pp. 146-152, March, 1915.

manufacture; there is controversy as to the origin of the Sunder terrace in Maryland and Virginia, but no geologist will deny certain houses have been built on the surface of the Sunder terrace flat; although the geologic history of the pre-Camb formations in Michigan and in other areas adjacent to the G Lakes may be inadequately known, no one is justified in denying such a reason that glacial deposits overlie the geologically old rc as it is obvious that the overlying material has in some way placed on the underlying. The superposition of a geologic forma on another may be recognized without knowing the complete his of either the upper or the lower. The oligocene coral reef a Flint River near Bainbridge, Georgia, rests on the eroded surface upper Eocene limestone now designated the Ocala limestone. knowledge of the Ocala limestone may not be adequate does invalidate the recognition of the facts that the fossil reef overli and that an erosion period intervened between its deposition anc growth of the reef, which obviously formed during or after the mergence of its basement.

To ascertain the origin of the submarine flats on which offs reefs stand is important in the advancement of our knowledg geologic history, and I have acquired as much information on subject as I could. I am completely convinced that there is nc explanation that can be applied to all of them. The following k have already been recognized: (1) Slightly tilted bedded tuff, the fossil reefs of Antigua; (2) slightly tilted bed of limestone, the south coast of St. Croix and Cuba; (3) submerged coastal as in the Fiji Islands; (4) submerged peneplained surfaces, as in fossil reefs of Porto Rico; (5) submarine plains due to uplift of siderable areas of the ocean bottom and to the deposition of or deposits on such a surface, as the Floridian Plateau previous t formation of the middle and upper Oligocene reefs of Florida nd southern Georgia; (6) flats of complex and not definitely known o such as those of the Antigua-Barbuda Bank, the Virgin Bank, nd the continental shelves of tropical America and Australia. P suitable for the growth of corals have been formed by subaerial nd submarine deposition, and by both subaerial base-leveling and ub- marine plantation. Nearly every, if not every, plain-prod process operative in tropical and subtropical regions has taken art in the formation of plains on which corals have grown or are gro where the plains have been brought below sea level and whe other ecologic conditions for offshore reef formation obtain.

I will revert to this subject in discussing the Glacial-control th and in making suggestions as to future research.

ARING OF THESE CONCLUSIONS ON HYPOTHESES OF THE FORMATION OF CORAL REEFS.

How do my results compare with the theories and hypotheses vanced by others? Before considering my conclusions in their ation to those reached by other investigators, I wish to make a few ieral remarks on the literature appertaining to coral reefs. It is a ject that, in order to be properly treated, requires a considerable ersity of knowledge, as biologic, oceanographic, and geologic blems are involved. Very rarely has it been practicable for a man be a specialist in all of these fields. Usually, as any investigator s been specially qualified in only one or two of them, he has paid ticular attention to those subjects with which he was familiar, and rly always did good work in those subjects; but in those fields in ich he has been only casually engaged, his work is nearly always ateurish, and his conclusions are in many instances erroneous. ould we expect a man who is primarily a biologist to be an expert geology, especially when he attempts geologic work after he arrives the place where he expects to conduct his investigations, without ring had previous experience? Should we expect a man who has eted his attention on dry-land physiography, and who has not ught of biologic problems or of the physiography of the sea tom to take information from those branches of science? In ding the many publications on coral reefs, I am impressed with the ticular, personal interests of the investigators, but what strikes more forcibly is the excellence of nearly all the papers. I know paper by a serious scientific man on a coral-reef area that does not tain records of valuable observations and correct conclusions. I e had the wish to write an account of the very gradual growth of knowledge we now have of coral reefs, and point out how each of successive workers has contributed toward making that knowl- e what it now is. It would be a record of honorable achievement. I the short review to follow I trust I may point out some of the stantial additions to be credited to those whose opinions I shall cuss.

. The Darwin-Dana hypothesis, in my opinion, is correct as regards formation of offshore reefs during and after submergence; but as rards the formation of a prism of reef material, the upper surface which forms a flat behind the barrier, their theory is wrong for ery area on which we have definite information. Although the oretic possibility of the conversion of a fringing reef into a barrier l a barrier into an atoll may not be denied, no instance of such version has yet been discovered. The inferences of Darwin as to as of subsidence and of elevation, as shown on plate 3 of his work, largely in error, for barrier reefs are present where there is not ieral crustal subsidence, as Foye points out in his paper on the

geology of the Fiji Islands, where "since the Pleistocene period t algebraic sum of the movements has been positive and uplift h resulted."[1] Very many similar instances, the Bermudas, the Baham Florida, and Cuba among them, can be given. The criticisms of t Darwin-Dana hypothesis apply to the recent publications of W. Davis.

2. Semper, Alexander Agassiz, and others, who have maintain that barrier coral reefs have formed in areas of uplift, are correct, the sum total of the movements since some date back in Tertia time be considered, and their observations and deductions are val able in that they emphasize these facts; but they are in error in th they failed to take into account that in many areas there is incc trovertible evidence showing submergence of the basements of t now-living reefs. Semper made astute observations on currents, b his deductions as to the formation of lagoons by destructional pr esses are not warranted.

3. Sir John Murray invented a very stimulating hypothesis, a correctly emphasized the necessity of taking submarine planati into account in studies of the basements of coral reefs. He, howev overlooked important facts clearly proving Recent submergence coral-reef areas, and his theory of the formation of atoll lagoons a lagoon channels through submarine solution by sea water is entir disproved, and there are no other known destructional proces whereby lagoons may be formed, for lagoons are areas of sedimentati in which filling predominates over removal of material.

4. Guppy is correct in his interpretation of offshore reefs be superposed on submarine platforms or "ledges," and he made n merous valuable contributions to our knowledge of coral reefs, but failed to take into account evidence showing Recent submergence

5. Admiral Sir W. J. L. Wharton made one of the greatest c tributions to our knowledge of atolls when he discovered the flatn of the floors and the uniformity of depth in atoll lagoons, and pointed out the inadequacy of the Darwinian hypothesis to expl these phenomena. He emphasized the importance of submar planation in leveling the top of peaks that reach or almost reach level, and definitely suggested the superposition of coral patches atoll rims on flats produced in that way. He not only did not opp the subsidence of such flats, but he thought that they frequently "subside and that some of the deeper lagoons may owe their depth 50 fathoms or so to such a movement, quite apart from subside of large areas which we know occurs." The only emendations of th statements that I can suggest is that the probable effects of gla tion and deglaciation might have been considered.

[1] Nat. Acad. Sci. Proc., vol. 3, p. 309, 1917.

Alexander Agassiz correctly observed the superposition of the g coral reefs of the Bermudas and the Bahamas on older lime- e foundations that stood above sea level previous to the sub- gence which made possible the formation of reefs in the places e they now grow. He also pointed out the superposition of the idian, Cuban, and Central American living reefs on antecedent orms or older limestone. He showed that in several areas in the fic the sum total of local crustal movements since some time in Tertiary period had been upward. But he failed to take account ecent submergence in Florida, the West Indies, and Central rica, and he advanced the hypothesis that the living offshore of the Pacific are superposed on wave-cut platforms without ge of sea level by submergence of the land. I believe Agassiz ct in his emphasis of the need of an antecedent platform for the ous growth of offshore reefs; but he did not recognize the clear nce of Recent submergence of the shores of the reef-encircled ls, and unfortunately tried to explain the formation of lagoons ubmarine solution and scour.

7 E. C. Andrews, I believe, is incontrovertibly correct in the tials of his interpretation of the conditions under which the t Barrier Reef of Australia has formed; that is, it is superposed at part of the recently submerged Continental Shelf of Australia lies within the temperature zone favorable for the life of reef- ing corals.

8 Stanley Gardiner, who has made great contributions to our ledge of Indo-Pacific corals and coral reefs and whose work on e ceanography of the Indian Ocean is justly rated as classic, com- it d the same errors in interpreting the geologic relations of coral ef as did Murray and Agassiz. He failed to infer submergence or shore line characters and advocated the formation of lagoons gh submarine solution by sea water.

9 Hedley and Griffith Taylor agreed in all the essentials of ews's interpretation of the conditions under which the Australian Barrier formed; they opposed Murray's solution hypothesis for e rmation of lagoons, and correctly emphasized the importance of nts, largely wind induced, in the shaping of the atolls along the Barrier.

10 Daly did not originate the Glacial-control theory of coral ef but he is its principal exponent. The following ascertained ons of living offshore coral reefs conform to the demands of this p hesis: (*a*) They are superposed on antecedent basement flats;) e amount of recent submergence, between 30 and slightly more 20 fathoms, without deducting the amount of Recent up-build- g the sea bottom, which probably is as much as a few fathoms, o the order of magnitude expected from deglaciation; (*c*) the

rate of growth of corals is known to be of such an order of magnit as to account for the thickness of any known living coral reef the growth of coral-reef organism since the disappearance of last great continental glaciers. As Daly is not a specialist on cor he has made some errors in his discussions of the geologic hist and ecology of corals, but these errors do not affect the validity glacial control being one of the dominant factors in modern coral- development. The only important point on which I am not in ag ment with him is the evaluation of Pleistocene marine planation have shown that the Floridian Plateau has existed as a platea least since late Eocene time, and there have been extensive subma flats in certain West Indian areas since late Eocene or Oligocene t The submarine profiles that I have drawn for the West In Central America, and Australia indicate Pleistocene benchin depths between 26 and 36 fathoms, without deducting anythin Recent upbuilding of the sea bottom. Certain West Indian Central American reefs and the Australian Great Barrier, I, there believe are growing on what were dry-land areas during at le part of Pleistocene time. It, therefore, seems to me that mar the flats discussed by Daly are of *pre-Pleistocene* age, and that h over-evaluated Pleistocene marine planation. Daly admits that has been local crustal movement in some coral-reef areas.

11. Wood Jones is undoubtedly correct in attaching great portance to the effects of sediment on the formation of coral No one who has had actual experience with coral reefs can moment doubt it. He also correctly accepts the interpreta of Andrews and of Hedley and Griffith Taylor for the Great B of Australia, joining with the latter two in their opposition t solution hypothesis and in their emphasis of the effects of induced currents in shaping the segments of a reef. He, how appears not to have appreciated the importance that, in my opi should be attached to submergence as factor in coral-reef form

12. My own opinions can be very simply stated: (*a*) Fringing seem always to have unconformable basal contacts; they may be f after submergence that is not followed by uplift or during interm uplift that follows submergence; that is, they may form during p of either emergence or submergence of land areas. Are the basa tacts really significant? Must not these contacts in the very nat the case be unconformable? If the basement has moved up reference to sea level and a reef begins along the strand lin basement of the reef will certainly be different from the reef and there will be an obvious unconformity. If the land mas sides and a fringing forms along shore, the base of the reef will exhibit unconformable relations. I am unable to imagine a fr without an unconformable basal contact. I never saw one th

have such a contact. (*b*) Offshore coral reefs, barriers, and lls, form on antecedent flattish basements during and after submergence in areas where the general ecologic conditions are suitable coral growth, as stated on page 240. This generalization applies ossil as well as to living reefs. (*c*) Recent rise of sea level because leglaciation has made conditions favorable for coral-reef formation r enormous areas, and it is one of the important factors in causing great development of coral reefs at the present time. But in ne areas, as in the Fijis, the flats on which the reefs are growing coastal flats that have been brought below sea level by tilting, escribed by Andrews and Foye. (*d*) The theoretic possibility of progressive change of a fringing reef into a barrier and later into atoll, according to the Darwin-Dana hypothesis, may not be denied, no instance of such a transformation has as yet been discovered. The coral-reef investigation is of value to geology, not so much ause of what has been discovered regarding corals as it is that as led to the study of a great complex of geologic phenomena ong which corals and coral reefs are only incident. Further investions of the phenomena associated with coral reefs are among the t desiderata of geologic research.

Suggestions as to Future Investigations.

efore closing this discussion I will present a few suggestions that ne appear pertinent.

. It is my belief that, although ecologic notes are of much value ystematic work, not a great deal more advantage will result n such ecologic investigations in areas where corals are luxuriant hose conducted by Gardiner, Wood Jones, and others, including elf. We need to know more of the physiology of corals, but such arches must be conducted by expert physiologists. There is t need for ecologic work in the waters northward and southward n the coral-reef zone. Within the coral-reef zone there are three as delimited by depth and temperature. What happens outside coral-reef zone? Do the deeper-water forms live in shallower er as the high latitudes are attained? Is it depth or temperature causes the vertical faunal distribution within the Tropics? e knowledge of the ecologic relations of the deeper-water faunas e Tropics and of the faunas in both shoal and deep water in the berate zones of the ocean is of great importance to geologists, uch knowledge would furnish a basis for interpreting the physical litions under which some of the fossil faunas lived. For some s I have wished to make an investigation of the kind outlined, other duties have prevented the fulfilment of my desire. There large amount of morphologic work needed, both on the skeletons on the soft parts of corals, but particular consideration of this ect is scarcely in place here.

2. The study of sediments in coral-reef areas has scarcely been in ated. Accurate determination of the source of the constituent calcium-carbonate bottom-deposits should be made, the deposits sho be classified according to their constituents, at least the area occu by each kind of deposit should be ascertained as nearly as is pra cable, and an endeavor should be made to ascertain the rate which the different kinds of sediments accumulate. The results f investigations of this kind are of vital importance to geology, only by firmly basing our inductions on wide and accurate knowl of what is now happening in the ocean can we hope to make reli deductions concerning the origin of and the conditions under w older sediments were formed. The quantitative evaluation of work done by the different agents cooperative in the productio the different kinds of sediments should be an object constantl mind. Although this is essentially a new field of research, du the past few years a number of investigators have notable achi ments to their credit.

3. Detailed studies of the general geology of tropical islands and tinental areas adjacent to tropical and subtropical waters shoul undertaken wherever possible. These investigations should inc consideration of the stratigraphic and structural geology, the pe raphy of both the igneous and sedimentary rocks, very detailed on the stratigraphic paleontology, and the physiography of the areas. We now know that, by combining knowledge gleaned fron study of many relations, it is possible not only to recognize fo area the succession of rocks, their age equivalents in other areas, their deformational history, but that it is also possible to asce the successive physiographic stages and other physical condi throughout at least a considerable part of the history. The struc relations of the successive formations, the nature of the contac formations, and the character of the sediments, are among the cri to be used in making the latter kind of deductions. Of how m tropical areas are there topographic maps on a scale of 1 : 62,500 1 : 125,000? Many areas, where the geology is very complic should be mapped on a scale of at least 1 : 20,000. The very det studies of a few carefully selected areas would supply keys for areas and thereby accelerate work in other areas. Detailed of the kind suggested should be done in Antigua, St. Bartholo St. Martin, and Anguilla, in the West Indies, for each of these is typifies certain phenomena that are critical in elucidating the hi of the West Indies, Central America, the southern United St and northern South America.

4. Biogeographic investigations supply a basis for deductions re ing former land connections and the dates of the separation of is that may have been parts of large land masses.

Shore-line history is obviously an essential part of the study of al reefs. But the entire story can not be deduced from the information furnished by all of the lines of investigation above suggested. configuration of the sea bottom needs to be studied, both in n and profile. Notwithstanding the great amount of work that been done on oceanic hydrography, close attention to the minor figuration of the sea bottom and attempts to draw inferences from n studies are of very recent date. Since most hydrographic rts were not intended to serve as a basis for such researches, we fortunate that we can extract so much information from them. nough it is probable that a much larger amount of data is on charts than has as yet been utilized, that additional hydrographic arch is needed is obvious. What are submarine slopes off the de ends in reef-encircled islands? What is the character of the es off both the reefs and the breaks in the reefs? The problem submerged terraces, flats and fronts, has barely been touched. v extensively are such features present, and what is their significe? These considerations lead to inquiries regarding wave base, rate of motion of the water, the erosional and transporting power he water while in motion at different rates, and the relations of ion and transportation to depth. Although the factors mened are among those that determine the profile of subaqueous ilibrium and must be considered in their relation to it, there are er factors, among which are the initial slope of the bottom, the dness and degree of consolidation of the material forming the tom, and the attitude, height, and hardness of the rocks at the re. More information on this complex of problems is urgently ded.

ea level rises or falls with reference to the land, or the land rises falls with reference to the sea level. That there have been many ts in the position of the strand line since the beginning of Pleistoe time is known to every geologist. He also knows that in many s shifts have been caused by tilting or flexing of parts of the h's crust, and that there must have been lowering of sea level le there were great continental ice sheets, followed by rise of level when the ice sheets melted. How much of the geologically ent change in the position of strand line is to be attributed to atic causes and how much to differential crustal movement? e accurate and areally more extensive studies of shore-line his- should enable a more precise evaluation of the effects due to than is now possible. Such investigations must not be confined ropical and subtropical areas—they must be world wide.

hen there is the problem of Pleistocene wave cutting. I believe, reasons stated elsewhere, that Daly has overevaluated the effects leistoceme marine planation. Has either of us really enough

information to be convincing? Should answers to the questi raised in the preceding two paragraphs be forthcoming, and if can make reliable estimates of the duration of the Pleistocene, amount of marine planation while sea level was lowered in the Pl tocene might be more nearly approximated.

In conclusion, I wish to say that the questions and suggestions c tained in the foregoing remarks have grown out of a study of co and coral reefs and the phenomena associated with them; and though it may have been shown, that corals are not so important they were once considered to be, geolgists should be grateful for romantic interest inspired by these lowly animals, for this inte has led us into the presence of some of the profoundest problem geology. Perhaps the interest will endure and it may lead us t better understanding of the world of which we form a part.

SYSTEMATIC ACCOUNT OF THE FAUNAS.

Class ANTHOZOA.

MADREPORARIA IMPERFORATA.

Family SERIATOPORIDAE Milne Edwards and Haime.

1849. *Seriatoporidae* Milne Edwards and Haime, Comptes Rend., vol. 29, p. 262.
1869. *Pocilloporidae* Verrill, Essex Inst. Proc., vol. 6, p. 90.
1870. *Stylophoridae* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 1, p. 514.

In a recent publication[1] I have stated that while I seriously doubted the propriety of placing *Stylophora* and *Pocillopora* in separate families, the traditional usage was followed. Additional study since that statement was written has convinced me that *Stylophora*, *Seriatopora*, and *Pocillopora* all belong to the same family. In fact, it seems that both *Seriatopora* and *Pocillopora* are derived from *Stylophora*, mostly through retrogression in the development of the colony. It is hoped to present in a future paper the evidence on which this suggestion is based.

Genus STYLOPHORA Schweigger (emend. Milne Edwards and Haime).

1819. *Stylophora* Schweigger (part), Beobacht. auf Naturf., pl. 5.
1820. *Stylophora* Schweigger, Hand. Naturg., p. 413.
1830. *Stylophora* and *Sideropora* de Blainville, Dict. Sci. nat., vol. 60, pp. 319, 351.
1835. *Anthopora* Gray, Zool. Soc. London Proc. for 1835, pt. 3, p. 86.
1846. *Sideropora* Dana, U. S. Expl. Exped. Zooph., p. 517.
1850. *Stylophora* Milne Edwards and Haime, Ann. Sci. nat., ser. 3, Zool., vol. 13, p. 102.
1857. *Stylophora* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 133.
1861. *Stylophora* de Fromentel, Intr. Polyp. foss., p. 179.
1884. *Stylophora* Duncan, Linn. Soc. London Journ., Zool., vol. 18, p. 45.

Type-species.—*Madrepora pistillata* Esper.

Duncan in his papers on the Fossil Corals of the West Indies either describes as new or lists the following species:

From the Eocene of Jamaica:

Stylophora contorta (Leymerie) + 1 var.

From the Eocene of St. Bartholomew, Cleve collection:

Stylophora compressa[2] Duncan.
distans (Leymerie).

[1] Carnegie Inst. Washington Pub. 213, p. 73, 1918.
[2] Although I have studied the collection from St. Bartholomew submitted to Duncan, I could recognize only the species which I have divided into four varieties.

Stylophora conferta Reuss.
tuberosa Reuss.
affinis Duncan (described from Santo Domingo)
granulata Duncan (described from Bowden, Jamaica).

From Santo Domingo:
Stylophora affinis Duncan.
var. *minor* Duncan (a valid species).
raristella (Defrance).

From Bowden, Jamaica:
Stylophora granulata Duncan.

From St. Croix, Trinidad:
Stylophora minuta Duncan.
raristella (Defrance).
mirabilis Duncan (not Duchassaing and Michelo

I described in 1900 [1] *Stylophora ponderosa* from the Oligocen Salt Mountain, near Jackson, Alabama, and *Stylophora minutis* from the Oligocene of Blue or Russell Spring, near Bainbri Georgia.

I recognize as valid the six species described as new by Duncan the two later described by myself. Duncan's identifications of W Indian specimens with European species are all discarded as they probably erroneous.

In addition to the six species here described as new, I have scribed six other species in manuscript not yet published, maki total of at least 20 species of *Stylophora* known to me from American Tertiary formations. The stratigraphic range of the g in America is from the upper Eocene to Miocene.

STYLOPHORA IMPERATORIS, new species.

Plate 74, figs. 1, 1*a*, 2, 3, 4, 4*a*, 5.

Corallum attaining a rather large size, the basal part of s colonies as thick as a man's wrist. The cross-section of bran ranges in form from subelliptical to curved lamellate. The follo are the diameters of the broken ends of the specimen, which is mm. long, represented by plate 74, figure 1.

Diameters in millimeters of branches of Stylophora imperatoris.

	Lesser diameter.	Gr diameter.
Basal end	14.5	27.0
Smaller branch	13.0	17.5
Wider branch	9.5 to 16	24

[1] U. S. Geol. Survey Mon. 39, p. 132, 1900.

The branch terminals are compressed and often form sinuous p tes. Thickness just below the summits about 3 mm.; width very v iable, ranges from 6 or 7 up to 25 mm. Nodule-like growths are f quent on the sides of older branches.

Calices on older parts of the corallum from 1 to 1.3 mm. in diameter, t refore rather large and conspicuous; intervening walls from 0.75 t 2 mm. across, usually about 1.25 mm. Near and on the branch s mits the calices are usually crowded and slightly less than 1 mm. i diameter. Upper margin of the calices usually more prominent t n the lower, sloping slightly downward, externally finely costulate.

Septa, 6 primaries distinct, well developed, extending to the col- u ella, the directives more prominent than the other primaries; s condaries are small or obsolete, if they were present they usually h e been destroyed in the type and paratypes of the species.

Columella, a small, only slightly prominent style.

Coenenchyma dense; its surface beset with pointed granulations.

Localities and geologic occurrence.—Canal Zone stations 6016, in the E perador limestone, quarry, Empire, where some hundreds of s ecimens were obtained; 6024*b*, lower end of culvert, Panama R lroad (relocated line), on Rio Agua Salud, in the upper bed, col- l ted by T. W. Vaughan and D. F. MacDonald. Station 6026, in the C ebra formation, 2½ miles south of Monte Lirio, Panama Railroad r located line), collected by T. W. Vaughan and D. F. MacDonald. A guilla, station 6894, bluff, south side of Crocus Bay, in the lower 5 feet of the exposure, collected by T. W. Vaughan. (See pl. 7 figs. 4, 4*a*.)

Doctor MacDonald obtained the specimen represented by plate 7 figure 5, at station 1863 of the canal commission, on the west si of Gaillard Cut, between points opposite Cucaracha and Paraiso, st ion 5853 of the United States National Museum locality register. T specimen came from a layer, about 2½ feet thick, consisting of p bles, gravel, and tuffs cemented with calcareous material; below th layer is gray, flaggy sandstone and tuff beds; above it is gray, fl gy sandstone, in thin layers separated by partings of carbonaceous bl k shale. The geologic horizon therefore seems to be in the Culebra fo nation, probably near its top. The specimen appears to be a form of *Stylophora imperatoris* in which the calices are more crowded than u al, as it agrees with that species in all other characters.

Type.—No. 324752, U.S.N.M.

Paratypes.—Nos. 324753, 324754, U.S.N.M.

STYLOPHORA PANAMENSIS, new species.

Plate 75, figs. 1, 1*a*.

Corallum, branches more or less contorted plates (see pl. 75, fig. 1). T thickness of the lower end of the type is 12.5 mm.; width, e ceeds 28 mm.; length from base to summit, 38 mm.

Calices small, apertures from 0.5 to 0.75 mm. in diameter; crowd maximum distance apart 1 mm., usually less than 0.5 mm.—that less than a calicular diameter apart. Margins very slightly or at all elevated; upper wall in places forms an obscure upper lip.

Septa, the six primaries distinct, fuse in the calicular axis, direc plane well marked; secondaries not recognizable in the type-sp mens and appear to be absent, but it is possible that they were pres and have been destroyed by fossilization.

Columella a compressed style, not prominent.

Coenenchyma, surface badly worn in the type, but some gran tions may be distinguished.

Locality and geologic occurrence.—Canal Zone, station 6016, in Emperador limestone, quarry, Empire, collected by T. W. Vaug and D. F. MacDonald.

Type.—No. 324763, U.S.N.M.

S. panamensis has smaller and more crowded calices than *imperatoris*.

STYLOPHORA AFFINIS Duncan.

1863. *Stylophora affinis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p pl. 16, fig. 4.

1866. *Reussia affinis* DUCHASSAING and MICHELOTTI, Sup. Corall. Antilles, (of reprint).

1867. *Stylophora affinis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p 5.

1870. *Reussia affinis* DUCHASSAING, Rev. Zooph. Antilles, p. 26.

Original description.—"Corallum branched, large; branches ne cylindrical, leaving the stem at an acute angle, slightly flattene one side. The largest stem is four-fifths inch in diameter. B aborted, branchlike swellings exist on some of the larger st Corallites radiating from the center of the stem and branches, s rated by about their own width of dense coenenchyma, which is in the larger specimens, to be very slightly cellular. Walls not di guishable from the coenenchyma in the substance of the mass, slightly raised into a very shallow crateriform edge on the sur Calices circular, a very little raised as crateriform elevations, numerous, disposed irregularly, but very nearly equidistant in places and less so in others; margins sharp. Diameter one-thir inch [0.83 mm.], rarely larger. The calicular margin, when well re served, looks like a little ring placed on the intercalicular space the small styliform columella renders the appearance very dist Intercalicular spaces marked by a continuous and rigid line, w being in the part of the spaces at the base of the calicular e tions, and being continued round each calice, is, from its ge straightness, formed into irregular polygons. The line is sen raised, convex, and now and then dentated. Between the lin the calicular margin there are distinct papillae, one row at the

rginal edge, the other corresponding to it a little lower down the icular wall; a third is sometimes seen; and in places where there s an unusual distance between the calices, and when the 'line' is ating, the papillae are numerous, distinct, and a little smaller. e line and the papillae form a very marked distinction. Between e calices there are faint elevations. Septa whole, not exsert, but le visible in perfect calices, but very distinct when the coral is n. Upper margin perfect and concave upward, the septa ap- ring festooned to the columella; they are delicate, very little ker at the wall than elsewhere, and join the columella high up r its point. The papillae at the calicular edge extend a little on wall, and may be considered as rudimentary septa and costae; , there is a second cycle, and also a third in half of each system. persistence of six septa, nearly all of the same size, is very re- kable. Columella styliform, large and dense in the corallite, and ning a rounded-off cylinder with a sharpish rounded tip, which is y distinct halfway down the calice. Calicular fossa shallow, ut half as deep as broad. Endothecal dissepiments stout, trans- se, numerous. The walls and columella do not fill up the lower ts of the corallites. Increase by extracalicular gemmation.

From the Nivajé shale. Coll. Geol. Soc."

Duncan reports the species from the Nivajé and Cerro Gordo es, Santo Domingo.

I have received 22 specimens labeled *Stylophora affinis* from the seum of Comparative Zoology, and 6 from the Philadelphia demy of Sciences. I have separated four of the specimens be- ging to the former institution and have described them as a new ies. Six specimens are *S. affinis*, 9 are worn but probably are *affinis*, 2 seem to be different and possibly belong to a different ies, 1 I refer to Duncan's *S. granulata*. I think that two of adelphia Academy are referable to *S. affinis*, the four others are bably worn specimens of the same species.

In the specimens that I have referred to *S. affinis* the upper margin the calice is more prominent than the lower forming a small, pro- ing lip. Duncan's description in other respects is satisfactory. The surface of specimens is easily worn by rolling, the upper lip the calice and the surface ornamentation being destroyed, the ctive identification of many specimens is rendered impossible. the tips of the branches, which are blunt and rounded, the calices crowded, with no development of intervening coenenchyma.

Miss Maury obtained in Santo Domingo a single specimen, a piece small branch, of this species, on Rio Gurabo, zone D, associated *Madracis decactis* (Lyman), *Pocillopora crassoramosa* Duncan, *hanocoenia intersepta* (Esper), *Orbicella limbata* (Duncan), *cella cavernosa* var. *cylindrica* (Duncan), and *Syzygophyllia ata* (Duncan),

I collected at station 3446, in the La Cruz marl, first deep cutt
east of La Cruz, near Santiago, Cuba, casts of the surface of a spe
of *Stylophora*. Squeezes of the surfaces of these casts agree c
pletely with specimens from Santo Domingo identified by m
S. affinis. I am therefore attaching that name to the specim
It is probable that similar casts from other localities in Cuba re
sent the same species.

STYLOPHORA PORTOBELLENSIS, new species.

Plate 76, figs. 1, 1a.

Corallum ramose, branches compressed, more or less conto
flabellate at the terminals. Growth form, therefore, similar to
of *Stylophora imperatoris*. The type is 37.5 mm. long; sm
diameter of basal end 10 mm., width of base about 13 mm.; maxin
width of branch in horizontal plane about 22 mm., thickness at s
level 10 mm.

Calices shallow, diameter averages about 0.75 mm. or slig
less; distance apart approximately equals the calicular diam
in places less, 0.25 to 0.5 mm.; margins flush with the coenenchy
surface, in places slightly elevated on the upper side, but not enc
to form a distinct upper lip.

Septa, six primaries distinct, rather thin, extend to the colum
no vestige of secondaries was observed.

Columella, a pointed style, moderately prominent, thickened b
the bottom of the calice.

Coenenchyma dense or costulate with an intercalicular ridge
cells on its sides. The surface is worn, but vestiges of small gr
lations may be recognized. Axis of the corallum spongy.

Locality and geologic occurrence.—Panama, probably from
Porto Bello, collected by D. St. Clair; geologic horizon unknown

Type.—No. 324762, U.S.N.M.

This coral has considerable resemblance to *Stylophora goethalsi*
its calices are distinctly larger, and their upper margins are in
places slightly raised. *Stylophora imperatoris* has larger calices
distinct upper lips. *Stylophora portobellensis* appears most cl
related to *Stylophora affinis* Duncan, from the Nivajè shale of S
Domingo.

STYLOPHORA GOETHALSI, new species.

Plate 75, figs. 2, 3, 4.

Corallum ramose, with branches subelliptical or much compr
in cross-section, in this character resembling *S. imperatoris*. Br
summits frequently or usually with digitiform protuberances
pl. 75, fig. 2).

Calices shallow, decidedly small, 0.5 to 0.75 mm. in diameter
relatively distant, from a calicular diameter up to 1.5 mm. a

cular margins obscurely or not at all elevated; without a pro-
erant upper lip.

epta, six distinct primaries, about equal in size, extend to the
olumella; secondaries much smaller, but can be distinguished in
better preserved calices.

olumella a small, slightly compressed, fairly prominent style.

oenenchymal surface closely set with pointed granulations.

ocality and geologic occurrence.—Canal Zone, at stations 6016,
ry in the Emperador limestone, Empire, Canal Zone, collected
T. W. Vaughan and D. F. MacDonald; 6026, in the Culebra
nation, 2½ miles south of Monte Lirio, Panama Railroad (relocated
, collected by T. W. Vaughan and D. F. MacDonald.

otypes.—No. 324767, U.S.N.M. (3 specimens).

ylophora goethalsi resembles the Santo Domingan species, *S. minor*
can, which is ramose and has small calices, from 0.5 to 0.75 mm.
iameter. The end of the branches in *S. goethalsi* are more com-
sed than in *S. minor*, its calices are slightly larger, and its
ondary septa are better developed. Although closely related,
appear to belong to distinct species.

STYLOPHORA MACDONALDI, new species.

Plate 75, figs. 5, 5*a*, 6, 6*a*, 7, 7*a*.

orallum composed of elongate, slender, curved branches and
chlets, with bluntish, rounded summits. The only branch
inal that is perfect is represented by plate 75, figure 5. The
lowing are measurements of four broken branches:

Measurements in millimeters of branches of Stylophora macdonaldi

Branch No.	Length.	Diameter of smaller end.	Diameter of larger end.
.....	15.5	3.5 by 5.0	5.0 by 5.3
.....	19.0	4.0 by 6.5	5.5 by 7.5
.....	21.5	4.5 by 5.0	5.0 by 6.5
.....	28.0	4.0 by 4.0	4.5 by 5.5

st below the place of bifurcation the parent branch is consider-
compressed; in one branch the greater diameter below a fork
mm., while the lesser diameter is only 6.5 mm.

lices rather shallow, but distinctly excavated; diameter, 1 mm.;
nce apart from 0.5 to 1.5 mm., usually less than the calicular
eter; margins usually slightly or not at all raised, but knots
spond to the outer ends of the septa. There is no upper lip to
alices.

pta, six well-developed, strong, subequal primaries extend to
columella; secondaries small but usually distinct. Subequal
s correspond to the outer ends of the two cycles of septa, and a

smaller knot with no corresponding septum usually occurs betw
each pair of larger knots.

Columella, a distinct, round, moderately prominent style, v
slightly compressed in the directive plane.

Coenenchymal surface roughly granulated, from 1 to 4 row
granules between calices, depending on their distance apart.

Localities and geologic occurrence.—Canal Zone, in the Empers
limestone at stations, 6016, quarry, Empire; 6024*b*, lower end of
vert, Panama Railroad (relocated line), on Rio Agua Salud in
upper bed, collected by T. W. Vaughan and D. F. MacDonald.

Cotypes.—No. 324769, 324770, U.S.N.M. (7 specimens).

Of other species of *Stylophora* with which I am acquainted *S.*
donaldi seems to resemble most *S. granulata* Duncan from Bow
Jamaica. *S. granulata* has deeper calices, less developed secon
septa, and in some specimens the upper lip of the calices is
prominent than the lower.

STYLOPHORA GRANULATA Duncan.

1864. *Stylophora granulata* DUNCAN, Geol. Soc. London Quart. Jour., vo
p. 10, pl. 2, fig. 3.
1867. *Stylophora granulata* DUNCAN, Geol. Soc. London Quart. Jour., vo
p. 25.
1873. *Stylophora granulata* DUNCAN, Geol. Soc. London Quart. Jour., vo
p. 551.

Original description.—"The corallum is ramose; the branches
nearly cylindrical, often flattened on one side, and leave the ste
an acute angle. The calices are placed irregularly, and are separ
by a coenenchyma, which is sharply granular, and which has
rarely any grooves or continuous ridges on its surface. The c
are circular, not inclined, very deep, and are surrounded by a
ring formed by the septa and costae. The columella is situ
deeply; it is cylindrical below, and sharp where free, but it doe
reach the level of the calicular margin; it is delicate, and six
septa are attached to it low down. The septa are in two sets.
superficial septa are from eighteen to twenty in number; six are
tinuous with the large septa, and the rest taper finely internally
externally, the spindle-shaped process being one-half septum an
rest costa. The processes are close, radiate, and horizontal. D
eter of calices, one-thirtieth inch [0.8 mm.].

"Localities: Bowden and Vere, Jamaica."

Duncan, in 1873, cites this species from St. Bartholomew, but
I am convinced, is an erroneous identification.

There are two small broken branches of this species in the c
tion of Mr. T. H. Aldrich, obtained at Bowden, Jamaica, and
sented to the United States National Museum.

Specimen No. 1.—Small branch, 16 mm. long, diameter of lower
. 4 mm.; upper end flattened, bifurcating, greater diameter 5.5
m., lesser 3 mm.

Diameter of calices very slightly less than 1 mm., separated by
ut the same width of coenenchyma. The margin is usually a very
htly elevated rim without an elevated lip around which are 12 to
small costae. In a few instances the costae continue from one
ce to the next, but usually the intercalicular coenenchymal sur-
e is merely granulate. There are from two to six indefinite zones
wavy lines of granulations between two calices. The granula-
s are subconical, round-pointed. Limits of zooids sometimes
tly indicated by a slightly raised granulated line. Calices mod-
ely deep. Six principal septa, the second cycle represented by
ll short septa, variable number of rudimentary members of the
d. The upper margins are slightly exsert.

olumella does not reach to level of calicular margin, sharp-
nted.

pecimen No. 2.—A small somewhat compressed, broken branch,
nm. long; greater diameter of lower end, 6.5 mm., lesser, 5 mm.;
ater diameter of upper end, 6 mm., of lesser, 4 mm. Diameter of
ces very slightly more than 1 mm. Width of intervening coenen-
ma averages about the same as the diameter of the calices.
cular rim a little elevated, and slightly swollen around the base.
ostae longer than in No. 1. Granulations about the same in both
imens. Elevated line between zooids usually distinct.

here is in this collection a third specimen which is probably only
riation of the same species. It is a fragment of a branch 14 mm.
g. The diameter of the calices is about 0.75 mm.; the calicular
s are not elevated but usually tend to be depressed. The coenen-
mal surface is very densely and minutely granulate. The limits of
oining zooids are indicated either by a very faint raised or by an
ressed line.

ocalities and geologic occurrence.—Besides occurring in the Bowden
l of Jamaica, *Stylophora granulata* is also found in Cuba at sta-
s 3476, Baracoa, and 3461, gorge of Yumuri River, Matanzas,
ected by T. W. Vaughan.

anto Domingo, station 7781, Rio Cana, zone H, collected by Miss
. Maury.

STYLOPHORA CANALIS, new species.

Plate 76, figs. 2, 2*a*.

orallum of type, a small, nodular mass, 42 mm. long, 23 mm. tall,
from 10 to 14 mm. thick (see pl. 76, fig. 2, for view, natural size,
ne upper surface).

Calices shallow, fairly large, 1 mm. in diameter; usually 1 m apart. Margins not elevated; the walls barely distinguishable fr the surrounding coenenchyma.

Septa in two distinct cycles; only the six primaries reach columella, but the secondaries are well developed.

Columella, a pointed style.

Coenenchymal surface crossed by costules, along which are re tively coarse granulations. In places the coenenchyma appears lular, as the costules are not solidly fused but have cellules develo between them.

Locality and geologic occurrence.—Canal Zone, station 6016, in Emperador limestone, quarry, Empire, collected by T. W. Vaugh and D. F. Macdonald.

Type.—No. 324775, U.S.N.M.

This species most closely resembles a species from the base of Chattahoochee formation, on Flint River, 4½ miles below Bainbric Georgia, but it differs from the latter species in two charact namely, the outer ends of the principal septa are not produced i prominent teeth, and in places the coenenchyma is distinctly cellu

STYLOPHORA PONDEROSA Vaughan.

1900. *Stylophora ponderosa* VAUGHAN, U. S. Geol. Survey Mon. 39, p. 132 13, fig. 16; pl. 14, figs. 1, 1*a*, 1*b*.

One of the specimens obtained by me in Antigua seems refer to this species. The upper surface has four nipple-shaped elevati on it; the largest is about 15 mm. in diameter at the base, ab 5 mm. tall, and about 5 mm. in diameter just below the roun summit. Except such protuberances, the surface is flattish, v some undulations. The size of the calices and the septal charac are as in the cotypes of *S. ponderosa*.

Localities and geologic occurrence.—Alabama, Salt Mountai miles south of Jackson, just above the top of the Vicksburg gr collected by T. W. Vaughan.

Antigua, station 6854, Rifle Butts, in the Antigua format collected by T. W. Vaughan.

Genus POCILLOPORA Lamarck.

1816. *Pocillopora* LAMARCK, Hist. nat. Anim. sans Vert., vol. 2, p. 273.
1918. *Pocillopora* VAUGHAN, Carnegie Inst. Washington Pub. 213, p. 75.

Type species.—*Pocillopora acuta* Lamarck.

Duncan described two fossil species of *Pocillopora* from the W Indies, *P. crassoramosa* [1] from the Nivajè shale of Santo Domi and *Pocillopora tenuis* [2] from Antigua. I have seen good suit

[1] Geol. Soc. London Quart. Journ., vol. 20, p. 40, pl. 5, figs. 2*a*, 2*b*, 1864.
[2] Idem, vol. 24, p. 21, pl. 1, figs. 5*a*, 5*b*, 5*c*, 1867.

pimens of *P. crassoramosa*, but have seen none of *P. tenuis*. *crassoramosa* has thickish branches on which verrucae may be e developed or obsolete; *P. tenuis* appears to be of more or less sive growth-form and has across the corallite cavities thin ulae, the spaces between which are not filled by steroplasmic osit.

have specimens representing four additional American fossil ies of the genus. They are all branching forms. I collected of the species at Willoughby Bay, Antigua, in the Antigua forma-; and another in the upper Oligocene marl at Baracoa, Cuba. specimen at the latter locality was obtained in association with *ophora granulata* Duncan, which was originally described from the den marl of Jamaica. Miss Carlotta J. Maury obtained *P. oramosa* in Santo Domingo in what she designates zone D, which ove the horizon of the Bowden marl. The geographic range of genus in the West Indies is, therefore, from the Antiguan ocene to a horizon appreciably above that of the Bowden marl.

POCILLOPORA ARNOLDI, new species.

Plate 76, figs. 3, 3*a*, 3*b*.

he type, which is a fragment of a branch, is 28 mm. long, diameter wer end 6.5 by 12 mm., diameter of upper end 5.5 by 9 mm. cross section of the branch is strongly compressed, and one side and at a place of bifurcation is concave instead of being convex. e are no verrucae.

Clices slightly oblong, lesser diameter about 0.75 mm., longer eter, parallel to the axis of the branch, from 1 to 1.25 mm. ies rather deep, about 0.5 mm., and steep-walled. Intercorallite flattish, arched, or slightly crested in profile, of unequal width, 0.3 mm. to 1 mm. across. Coenenchymal surface granulo-late, granulations fairly coarse.

Septa rudimentary, occur as low, blunt-topped, perpendicular s on the inside of the calicular walls. In some calices 12 of ridges may be distinguished. The bottom of the calice is flat ry gently concave; no vestige of a columella could be found.

Coenenchyma solid; corallite cavities solidly filled except a few e axis of the branch.

Locality and geologic occurrence.—Canal Zone, station 6444, quarry e Emperador limestone, Empire, collected by Dr. Ralph Arnold, e name I take pleasure in attaching to this well-marked species.

Type.—No. 324782, U.S.N.M.

Of the other five fossil species of *Pocillopora* known from the ary formation of the West Indies and Central America, the ned species from Antigua, previously mentioned, is the most ir. The latter species is composed of small, more or less com-

pressed branches, it has no verrucae, the calices are rather deep
septa are perpendicular ridges down the inside of the calicular w
and there is no trace of a columella. In these characters the tw
similar. The species from Antigua differs from *P. arnoldi* by ha
larger calices, lesser diameter 1 mm. or more, usually more than 1
and the calicular margin is rather persistently marked by a sli
raised acute rim. A description of the species from Baracoa, C
follows.

POCILLOPORA BARACOÄENSIS, new species.

Plate 77, figs. 1, 1*a*.

This species may be characterized as follows:

The corallum is branching; it has no verrucae and no colum
tubercle. The branch is regularly subcircular or broadly ellip
in cross section, 10.5 mm. in diameter at lower end. The calice
very shallow and are subcircular in outline, about 0.75 mm
diameter, distance apart usually slightly more than the cali
diameter. Thick short septa join the columellar plug to the
Coenenchyma very dense.

These characters are different from those of any of the other k
American species.

Locality and geologic occurrence.—Cuba, station 3476, in y
argillaceous marl, Baracoa, associated with *Stylophora gran*
Duncan, collected by T. W. Vaughan. The geologic horizon o
species is that of the Bowden marl.

Type.—No. 324783, U.S.N.M.

POCILLOPORA GUANTANAMENSIS, new species.

Plate 77, figs. 2, 2*a*.

Corallum composed of irregularly shaped, more or less comp
and contorted branches, among which there is considerable
tomosis. The branches may be as much as 27 mm. wide, 7.5 m
thick near the summit, and 12 mm. thick at the base. The b
on which these measurements were made is 41 mm. long. Ve
entirely absent on the type.

Calices from 0.75 to 1.25 mm. in diameter; usually less th
about their diameter apart. They are deep pits without any r
of septa, except that in a few calices what appear to be thick r
tives are recognizable on the plug forming the calicular floor. C
lar margins usually even with the coenenchymal surface; in o
calices they are somewhat tumid and slightly elevated.

The columella is only a plug. Stout, horizontal tabulae p

Coenenchyma very dense. Surface in type worn, but appa
beset with spines or granulations and not costulate.

Locality and geologic occurrence.—Cuba, station 7514, ab
miles nearly due east of Monument H4 on the east boundary

S. Naval Reservation, Guantanamo, altitude about 400 feet a. t., in ls of the age of the Antigua formation, collected by O. E. Meinzer. *Type.*—No. 324784. U.S.N.M. This species differs so markedly m the other West Indian species of *Pocillopora* that comparisons h the other species seem unnecessary.

Genus MADRACIS Milne Edwards and Haime.

1849. *Axhelia* Milne Edwards and Haime, Comptes Rend., vol. 29, p. 69.
1849. *Madracis* Milne Edwards and Haime, Comptes Rend., vol. 29, p. 70.
1861. *Reussia* Duchassaing and Michelotti, Mém. Corall. Ant., p. 63 (of reprint).
1871. *Pentalophora* Saville-Kent, Proc. Zool. Soc. London for 1871, p. 283.
1884. *Madracis* Duncan, Linn. Soc. London Journ., Zool., vol. 18, p. 45.
1900. *Madracis* Vaughan, U. S. Geol. Survey Mon. 39, p. 128.
1901. *Axhelia* Vaughan, U. S. Fish Commission Bull. for 1900, vol. 2, p. 294.
1902. *Madracis* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 108.

Type-species.—*Madracis asperula* Milne Edwards and Haime.

MADRACIS MIRABILIS (Duchassaing and Michelotti).

1861. *Stylophora mirabilis* Duchassaing and Michelotti, Mém. Corall. Ant., p. 62 (of reprint), pl. 9, figs. 6, 7.
1901. *Axhelia mirabilis* Vaughan, U. S. Fish Commission Bull. for 1900, vol. 2, p. 295, pl. 1, figs. 3, 3*a*.

single fragment of a branch from Limon, Costa Rica, is 23 mm. ;, 2 mm. in diameter at the lower end, and 3 mm. in diameter below trifurcation at the upper end. The fragment is slightly ate in form, not quite straight, and is not so crooked as is usual he specimens of *M. mirabilis* with which I have compared it. septa are less exsert around the calicular margins then is usual he species. Although there are the differences indicated, they of the kind that may be produced by vegetative causes.

ocality and geologic occurrence.—Costa Rica, hills of Port Limon, 669 of H. Pittier collection; geologic horizon not known.

uba, station 3461, gorge of Yumuri River, Matanzas, 19 frag- ts collected by T. W. Vaughan in a marl of lower Miocene vden) age.

hese fragments perhaps should be referred to a new species; they appear more probably to be only a variant of *M. mirabilis*.

Family ASTROCOENIIDAE Koby.

Genus ASTROCOENIA Milne Edwards and Haime.

348. *Astrocoenia* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 469.
900. *Astrocoenia* Gregory, Palaeontol. Indica, ser. 9, vol. 2, pt. 2, p. 59. (Synonymy and elaborate discussion.)

ype-species.—*Astrea numisma* Defrance.

sides the five species of *Astrocoenia* recognized in the present ur, I have described one under the name of *Stylocoenia duerdeni*

from the Eocene of Jamaica,[1] which also occurs in the upper Eoc of St. Bartholomew. I describe as new the species from Antig (*A. decaturensis*), to which Duncan applied the name *Astrocoe ornata*.[2] This species is also found in the coral reef at the base of Chattahoochee formation on Flint River, near Bainbridge, Georg and near Guantanamo, Cuba. More critical study may lead to recognition of one or two additional species. The names of European species applied by Duncan and others to West Ind forms probably should be dropped from the literature.

ASTROCOENIA D'ACHIARDII Duncan.

Plate 78, figs. 2, 2*a*.

1873. *Astrocoenia d'achiardii* DUNCAN, Geol. Soc. London, Quart. Journ., vol p. 554, pl. 20, figs. 7, 7*a*.
1899. *Astrocoenia d'achiardii* VAUGHAN, Mus. Comp. Zool. Bull., vol. 34, p. 22

Dr. C. W. Hayes obtained in Nicaragua, "on or near the Pac coast," a specimen of *Astrocoenia* (pl. 78, figs. 2, 2*a*) that se referable to *A. d'achiardii*.

The corallum is ramose; branch somewhat compressed, le diameter of lower end 10.5 mm., greater diameter only slightly m than the lesser.

Calices from 2 to 3 mm. in diameter, measured between th summits; the diameter of the largest calice is 3 mm. Maxim thickness of walls between adjoining calicular cavities, 1 r Depth of calices about 1 mm.

Eight prominent septa reach the columella, with a small sep between each pair of the larger. The large septa are narrow ab the bottom of the calice, where they widen and fuse to the colum around which they show decided thickening. The calicular cav therefore, is steep-sided and relatively flat-bottomed.

The columella is a slightly prominent, compressed style.

Locality and geologic occurrence.—Nicaragua, on or near the Pa coast, in the Brito formation, collected by C. W. Hayes. Dr. H says regarding the Brito formation.[3]

> The greater part of the Brito formation is apparently barren of organic rem The only location at which fossils have been found are on or near the Pacific This, however, may be due to the fact that the rock exposures are not elsewh such a character as to facilitate the discovery of fossils, and the latter may po be more generally distributed than present knowledge would indicate. The f are confined almost wholly to the limestones and marly beds. They consist of c molluscan, and foraminiferal remains.

The Foraminifera, according to Dr. Joseph A. Cushman, indi an Eocene age.

[1] Mus. Comp. Zool. Bull., vol. 34, p. 235, pl. 37, figs. 1–4, 1899.
[2] Geol. Soc. London Quart. Journ., vol. 19, p. 425, pl. 14, fig. 7, 1863; Idem., vol. 24, p. 23, 1867.
[3] Geol. Soc. Amer. Bull., vol. 10, p. 312, 1899.

Astrocoenia d'achiardii was described from the upper Eocene of St. Bartholomew. Finding it on the Pacific coast of Nicaragua is additional evidence in favor of connection between the Atlantic and Pacific oceans across Central America during upper Eocene time.

ASTROCOENIA GUANTANAMENSIS, new species.

Plate 79, figs. 1, 1*a*, 2.

Corallum massive, with a rather uniformly rounded or more or less irregular surface. Type 55 mm. long, maximum width about 31 mm., height 38 mm. The corallum may be much larger.

Calices polygonal, shallow, almost superficial, small; maximum diameter about 1.75 mm. in diameter, 1.5 mm. usual, smallest calices about 1 mm. in diameter, measured between thecal summits. Intercorallite walls acute or flattish, usually less than 0.25 mm. wide, maximum width 0.5 mm.; crossed by subequal costae corresponding with all septa unless very narrow, when the edge of the wall is dentate instead of costate.

Septa 16 in number, 8 reach the columella; 8 small, about half the length of the principals; in most instances they are thicker in the wall than at their inner ends. Margins of the longer with about three dentations on each. Septal faces with sharp granulations.

Columella, a small, erect, central style.

Localities and geologic occurrence.—Cuba, station 7522, Mogote Peak, 0.5 mile east of east boundary of United States Naval Reservation, Guantanamo, south side of peak, altitude about 375 feet a. t., collected by O. E. Meinzer (type).

Antigua, station 6865, Jackass Point, St. John, collected by T. W. Vaughan.

Panama, station 6587, Tonosi, collected by D. F. MacDonald.

Type.—No. 324794, U.S.N.M.

Astrocoenia guantanamensis is most nearly related to *Astrocoenia incrustans* (Duncan) which is from the upper Eocene St. Bartholomew limestone, and is the next species here described. The calices of *A. incrustans*, a description of which follows, are rather deep and the intercorallite areas are flattish and costate.

ASTROCOENIA INCRUSTANS (Duncan).

1873. *Stephanocoenia incrustans* DUNCAN, Geol. Soc. London Quart. Journ., vol. 29, p. 553, pl. 20, fig. 6.

1899. *Stephanocoenia incrustans* VAUGHAN, Mus. Comp. Zool. Bull., vol. 34, p. 229.

Original description.—"The corallum is low in height, and incrusts rocky surfaces. The corallites are united by their rather thick walls, and are parallel. The calices are quadrangular or pentangular, and their margins are marked by the septa of the adjacent corallites.

The septa are subequal at the wall, and 16 in number; but c
eight reach the small and deep styloid columella; the others pro
very slightly, and are moniliform on their free edge. The pali
attached to the eight larger septa.

"Height of corallum, one-tenth inch [=2.5 mm.]. Breadth
calice, one-twentieth inch [=1.25 mm.]."

The following notes are based on the type-specimen:

It is a small thin fragment, 17.5 mm. long, 8 mm. wide, and 4 m
thick.

The calices are moderately deep polygonal, many are elongate,
smaller ones measure 0.9 mm. in diameter, an elongated one is
mm. wide and 2 mm. long. The walls are thin, about 0.2 mm. w
however, the upper edges of the septa are flattened and somew
expanded. No mural styles.

Septa, 16 in number, equal in thickness at the wall, thicker t
the spaces between; 8 extend to the columella, the laminae thi
between the portions surrounding the columella and the outer e
The other 8 septa are short. The margins are finely dentate.
tinct pali absent. Apparently dissepiments are present.

Columella styliform, rather prominent, compressed.

This coral can not be referred to *Stephanocoenia* because there
no pali and the septal margins are dentate, instead of being en
However, it exhibits all the characteristics of *Astrocoenia*. In
size of the calices, number of the septa, and character of the se
margins it resembles *A. duerdeni* (Vaughan), but differs from
species by the apparent absence of mural spines Notwithstan
this, it is not impossible that the type-specimen could be a po
of a corallum of *A. duerdeni*, the styles being absent from the
whence it was derived.

Locality and geologic occurrence.—Island of St. Bartholo
P. T. Cleve, collector; subsequently collected by T. W. Vaugha
the upper Eocene St. Bartholomew limestone.

Type.—University of Upsala.

ASTROCOENIA DECATURENSIS, new species.

Plate 78, figs. 3, 3*a*, 4, 4*a*.

1863. *Astrocoenia ornata* DUNCAN, Geol. Soc. London Quart. Journ., v
p. 425, pl. 14, fig. 7. (Not Milne Edwards and Haime.)

1864. *Astrocoenia ornata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24,

Corallum massive, rather large, upper surface with numerous
bosities. One specimen has a base 14 by 17 cm., respectively, a
smaller and greater diameter, and is about 8 cm. in height, an
has 19 cm. as the greatest diameter of the base.

Corallites polygonal, separated by walls that are never very t
rarely as much as 1 mm., upper edge usually if not always ma

a small raised, granulated line. The distal ends of the septa are duced as short costae to this line and often a granulation occurs ween each pair of costae. The diameter of the corallites ranges n 1.5 to 2.5 mm.; about 2 mm. is the average. Calices shallow. epta distant, normally 16 in number, of which 8 extend to the mella, occasionally 20, with 10 reaching the columella. Their er ends are slightly prominent on the wall and are equal in size. inner margins lie almost in a straight line or are very slightly avated but are regularly finely dentate, with four to seven teeth ach septum. These teeth are moderately acute and are directly quely upward and inward. Granulations on the faces minute, ited.

ndothecal dissepiments present, thin, not abundant.

olumella a strong style, upper end pointed but not very promi- t. There is some thickening of the inner ends of the larger septa re they fuse to the columella.

ocalities and geologic occurrence.—Georgia, station 3383, Hale's ding on Flint River, 7 miles below Bainbridge; and station 3381, e Springs, 4 miles below Bainbridge, collected by T. W. Vaughan. land of Antigua, West Indies, in the Antigua formation, collected Robert T. Hill.

uba, station 7523, south side of Mogote Peak, altitude 250 feet , one-half mile east of east boundary of the United States Naval ervation, near Guantanamo, collected by O. E. Meinzer.

ype.—Cat. No. 324789, U.S.N.M.

aratype.—Cat. No. 324788, U.S.N.M.

strocoenia ornata Duncan from Antigua (No. 12948, coll. Geol. London) is a massive species of *Astrocoenia*. It is silicified; the llites are crowded, polygonal, intervening walls thin, diameter of llites, 1.5 to 1.75 mm. Septa, 8 principal, 8 rudimentary, thin distant. Columella, a slender style.

ASTROCOENIA MEINZERI, new species.

Plate 79, figs. 3, 3a.

orallum composed of thick branches, with broadly elliptical cross- ion. Type, a broken, bifurcating branch. Length from broken a to fork, 50 mm.; diameter of basal end, 23.5 by about 24 mm. ameter of broken end of branch at fork, 23 by 24 mm. Length of en lateral branch from fork, 21 mm.; diameter of distal broken 17.5 by 20.5 mm.

alices rather large, diameter measured between thecal summits 2.5 to 3 mm.; depth, 1.25 to 1.5 mm. Intercorallite walls from to 1.5 mm. across where well preserved, about 0.75 mm. usual. laces the top of the wall is acute, but this condition is probably due

to weathering. Where the walls are wide there is usually a dist
intercorallite groove. Thick costae or mural teeth are prob
present on perfect specimens, but they are not distinct on the t
as its surface is worn.

Septa 16 in number; 8 principals extend to the columella, a
are short but thick. The principal septa slope in a concave curve t
bottom of the calice, and are narrow nearly to the level of the bo
of the calice; the smaller septa are narrow. All septa are thic
the wall, and the principals are fused by their thickened inner
around the columella. About seven small dentations were cou
on one long septum. Septal faces with small granulations.

Columella a low style, with rounded upper end; it with the i
septal ends fused around it forms a rather large columellar ma

Thickish dissepiments are present.

Locality and geologic occurrence.—Cuba, station 7522, Mogote I
0.5 mile east of east boundary of United States Naval Reserva
Guantanamo, south side of peak, altitude about 375 feet a. t.,
lected by O. E. Meinzer.

Type.—No. 324791, U.S.N.M.

The species most nearly related to *Astrocoenia meinzeri* i
d'achiardii Duncan from the upper Eocene St. Bartholomew
stone. The branches of *A. d'achiardii* are more irregular in f
for the same size branch the calices are larger, up to 3.5 mm
diameter, the intercorallite walls are not so wide, the outer pa
the septal margins are steeper, and the septal dentations are co
Notwithstanding these apparent differences, it should be adm
that larger collections may lead to combining the two supp
species.

ASTROCOENIA PORTORICENSIS, new species.

Plate 76, figs. 4, 4*a*; plate 78, figs. 1, 1*a*.

1901. *Astrocoenia ornata* VAUGHAN, Geol. Soc. London, Quart. Jour., vol. 57, 19

Not:

1838. *Porites ornata* MICHELOTTI, Specim. Zooph. diluv., p. 172, pl. 6, fig.

1857. *Astrocoenia ornata* MILNE EDWARDS and HAIME, Hist. nat. Corall., vol. p. 257

The following is a description of the type (pl. 76, figs. 4, 4*a*):

Corallum forming flattened, even palmate branches. The p
specimen, which is broken, has a greatest width of 53 mm., l
105 mm., and a thickness of 15.5 mm. at the lower and of 7.5 m
the upper end.

Calices, diameter from 1.0 to 1.5 mm., excavated but rather sha
outline polygonal, united by compact, rather narrow walls, v
range from 0.2 to 0.5 mm. across. The distal ends of the septa r
low costae.

Septa, 16 in number, 8 reach the columella and 8 are short or
rudimentary; a few dentations, usually about 3 or 4 on the m

each principal septum. Interseptal loculi about as wide as the ckness of the septa.

Columella an erect style, which does not reach the level of the upper e of the wall; its upper termination rounded; cross-section ellip-al.

Endothecal dissepiments present.

Localities and geologic occurrence.—Island Antigua in the Antigua mation. Collected by R. T. Hill and by T. W. Vaughan.

Porto Rico, station 3191, 4 miles west of Lares, in the Pepino forma-n, collected by R. T. Hill.

Canal Zone, station 6024*b*, in the Emperador limestone, at the ssing of the Panama Railway over Rio Agua Salud, collected by W. Vaughan and D. F. MacDonald.

Type.—No. 324785 U.S.N.M., from 4 miles west of Lares, Porto, pino formation, collected by R. T. Hill.

Paratype.—Cat. No. 324786, U.S.N.M.

The foregoing description is based on the type-specimen and does take into consideration the variation of the species. I obtained od suite of specimens at two exposures of the Antigua formation the island of Antigua. The branches range in form from greatly pressed to subcylindrical (see pl. 77, figs. 1, 1*a*, illustrations of a cimen from Willoughby Bay, Antigua). A segment from near base of a subcylindrical branch was collected on Rio Agua Salud, al Zone.

Genus STYLOCOENIA Milne Edwards and Haime.

1849. *Stylocoenia* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 469.

Type-species.—*Astrea emarciata* Lamarck.

STYLOCOENIA PUMPELLYI (Vaughan).

1900. *Astrocoenia pumpellyi* Vaughan, U. S. Geol. Survey Mon. 39, p. 149, pl. 17, figs. 7, 7*a*.

his species seems to belong to the genus *Stylocoenia*, as it has inter-llite pillars; but as some septa show dentations on their margins, original generic identification may be correct. It occurs in the of the Chattahoochee formation, near Bainbridge, Georgia, and in Vicksburgian deposits, as I stated in the original description.

Localities and geologic occurrence.—Georgia: Station 2326, Russell ing, Flint River, 4 miles below Bainbridge, collected by R. Pum-r (type, Cat. No. 158315, U.S.N.M.); station 3381, same locality the preceding, collected by T. W. Vaughan; stations 3383, col-ed by T. W. Vaughan, and 7078, collected by T. W. Vaughan, V. Cooke, and W. C. Mansfield, Hales Landing, Flint River, les below Bainbridge, in the base of the Chattahooche formation.

Antigua: Station 6881, Willoughby Bay, collected by T. W Vaughan in the Antigua formation.

Family OCULINIDAE Milne Edwards and Haime.

Genus OCULINA Lamarck.[1]

1816. *Oculina* Lamarck, Hist. nat. Anim. sans Vert., vol. 2. p. 283.
1849. *Oculina* Milne Edwards and Haime, Comptes Rend., vol. 29. p. 68.
1850. *Oculina* Milne Edwards and Haime, Mon. Brit. foss. Cor., Intr., p.

Type-species.—*Madrepora virginea* Ellis and Solander.

OCULINA DIFFUSA Lamarck.

1816. *Oculina diffusa* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 285.
1901. *Oculina diffusa* ? variety Vaughan, U. S. Fish Commission Bull. for vol. 2. p. 294, pl. 1, figs. 5, 5*a*.
1915. *Oculina diffusa* Vaughan, Washington Acad. Sci. Journ., vol. 5, p. 5
1915. *Oculina diffusa* Vaughan, Carnegie Inst. Wash. Yearbook No. 14, p.

Doctor MacDonald obtained seven pieces of branches of h species at the locality mentioned below. They are slender n resemble fragments from specimens of *Oculina diffusa*, which o either in water 10 to 16 fathoms deep or where the water is quiet. The specimens from Panama nearly duplicate those I scribed from Porto Rico.

Locality and geologic occurrence.—Canal Zone, station 5849, sw Mount Hope, Pleistocene, collected by D. F. MacDonald.

OCULINA VARICOSA LeSueur.

1820. *Oculina varicosa* Le Sueur, Paris Mus. Mém., vol. 6, p. 291, pl. 17, fig
1902. *Oculina varicosa* Verrill, Conn. Acad. Sci. Trans., vol. 11, pl. 32, figs 4 (refs. to literature).

A single nearly typical fragment of a branch was obtained.

Locality and geologic occurrence.—Canal Zone, station 5849, sw Mount Hope, Pleistocene, collected by D. F. MacDonald.

ARCHOHELIA, new genus.

Archohelia differs from *Oculina* solely by having a persistent corallite, whereas in *Oculina* there is no axial corallite. Pali or form teeth are present on all but the last cycle of septa. Colu trabecular, with some papillae on its upper surface.

Type-species.—*Archohelia limonesis* Vaughan.

The relations of this genus to the species described in my m graph on the Eocene and lower Oligocene coral faunas of the U States [2] under the names *Astrohelia neglecta, A. burnsi, Oculina burgensis, O. mississippiensis, O. singleyi, O. alabamensis, O. ha*

[1] Toula (K. K. Geolog. Reichsanstalt Jahrb., vol. 61, p. 489, pl. 30, fig. 1, 1911) applies the nam *lina gatunensis* to a piece of a branch of coral, but his description and figure are inadequate for t tification of the species.

[2] U. S. Geol. Survey Monograph 39, pp. 114-124, 1900.

ldrichi, and *O.? smithi* should be indicated. The species mentioned e axial corallites and generically resemble *Archohelia* except in details of the inner ends of the septa. The type-species of *rhelia* (the correct spelling of the name, instead of *Astrohelia*) is *drepora palmata* Goldfuss, which has no definite axial corallites, I have seen no pali or paliform lobes on its septa. The species which I applied the names *Astrohelia neglecta* and *A. burnsi*, as y possess axial corallite should be taken out of the genus *rhelia*. As it is not practicable just now to revise critically the ene and lower Oligocene species listed above, it will here only be ıtioned that they probably should be transferred to *Archohelia*.

ARCHOHELIA LIMONENSIS, new species.

Plate 80, figs. 1, 1*a*, 1*b*, 2, 3.

orallum composed of relatively slender branches. The following measurements of the cotypes:

Dimensions in millimeters of cotypes of Archohelia limonensis.

Branch.	Length.	Diameter.		Calices.	
		Lower end.	Upper end.	Diameter.	Exsert.
.....	25	4.5	4	2.5–3	1–3.5
.....	31	4.5	4	2–2.6	0.5–3.5
.....	33	4	3.5	2.3–3	1–7

he cavity of the axial corallite is about 2.25 in diameter. The going tables give the dimensions and amount of the projection ıe radial calices—the diameters stated are as measured from the ıide of the walls. The distance between adjacent calicular mar- is about 2.5 mm. on branch No. 2; in extreme cases it ranges o as much as 7 mm., as between some calices on branch No. 3. arrangement is in more or less definite spirals. Subequal or tly alternating costae, with closely granulate surfaces, cor- ond to all septa just below the calicular edges; lower down on corallite limbs they flatten and become subequal; they may inue on the coenenchymal surface or disappear. The calicular ties are excavated; moderately deep, about 1.5 mm.

pta normally in three complete cycles; primaries as a rule slightly r than the secondaries, both cycles reach the columella, and subequal, slightly exsert upper margins; tertiaries smaller than secondaries and have lower upper margins. Inner edges of the aries usually free, but in some systems they fuse to the sides of ded secondary septa. Single or double paliform teeth on the ends of the primaries and secondaries. Septal faces closely ulate.

Columella papillate.

Coenenchyma dense; with or without costal prolongations t the calicular peripheries; fine granulations scattered over its sur

Localities and geologic occurrence.—Costa Rica, Limon, as foll Station 2692, collected by R. T. Hill; Moin Hill, Niveau *d* and 461, collected by H. Pittier; station 5884*b*, Moin Hill, collecte D. F. MacDonald. The geologic horizon seems to be Pliocene.

Florida, station 3300 in the Pliocene Caloosahatchee marl of Creek, collected by Frank Burns.

Cotypes.—No. 324809, U.S.N.M., from Niveau *d*, Moin Hill, Limon (3 specimens).

Family EUSMILIIDAE Verrill.

Genus ASTEROSMILIA Duncan.

1867. *Asterosmilia* Duncan, Roy. Soc. Philos. Trans., vol. 157, p. 653.
1873. *Asterosmilia* Duncan, Geol. Soc. London Quart. Journ., vol. 29, p. 5
1884. *Asterosmilia* Duncan, Linn. Soc. London Journ. Zool., vol. 28, p. 61

Type-species.—*Trochocyathus abnormalis* Duncan.

When Duncan described this genus he referred to it his *Tr cyathus abnormalis*, changing the name to *anomala*, and refig the species. He also described two additional species as *A smilia exarata* and *A. cornuta*, a synonym of *A. abnormalis*, failed to designate a type-species for the genus. *Trochocy abnormalis* was described with much care, while the descriptio the two other species are short and unsatisfactory. *A. cornut* synonym of *A. abnormalis*. It therefore seems best to take species I have selected, as indicated above, as the type-speci the genus.

Duncan described three species of *Asterosmilia* from the Ter formations of Santo Domingo, namely, *Trochocyathus abnorm* for which the genus *Asterosmilia* was subsequently erected, *A nuta*, and *A. exarata*,[1] and one species *A. pourtalesi* from the Eocene St. Bartholomew limestone. I consider *A. cornuta* a nym of *A. abnormalis*, and transfer Duncan's *Trochocyathus profu* from the genus in which it was originally placed to *Asteros* leaving four described fossil species in the genus. Pourtalès desc from the West Indies one recent species that belongs to *Asteros* his *A. prolifera*, originally named *Ceratocyathus prolifer*, and of Lindstrom's *Paracyathus arcuatus* is a synonym. I here descri additional new species, namely, *A. hilli*, from Bowden, Jamaica Limon, Costa Rica, and have described two additional species Santo Domingo, in a paper not yet published, making eight, the number of American species at present known to belong to the g

[1] Collected by A. Olsson on Provision Island, Costa Rica, in the Gatun formation. Footnot to page proof.

ASTEROSMILIA HILLI, new species.

Plate 80, figs. 4, 5, 6, 6*a*.

1899. *Asterosmilia* species VAUGHAN, Mus. Comp. Zool. Bull., vol. 34, p. 149.

find it difficult to explain why a species so common as this one d have so long remained undescribed. There are from Bowden, aica, 41 specimens in the Henderson and Simpson collection, 20 in Hill collection, and 9 in the T. H. Aldrich collection, making tal of 70 specimens that I have studied from this one locality. ries of ten of the best specimens of the Henderson and Simpson ction have been selected as the cotypes.

rallum cornute with a pointed base and attached, at least in its stages, rather slender, curved in the plane of the greater trans- axis of the calice. The following table gives the measurements number of septa in the type specimens.

Dimensions of and number of septa in Asterosmilia hilli.

men No.	Greater diameter of calice.	Lesser diameter of calice.	Height of corallum.	Number of septa.
	mm.	*mm.*	*mm.*	
.....	4	3	6.5	About 24, and probably some rudimentary.
.....	4	3.75	7	24, and a few rudimentary.
.....	4	3.5	9	24, and a few rudimentary.
.....	4.5	4	10.5	24+17 of the fourth cycle.
.....	6.5	5.5	12	24+20 of the fourth cycle.
.....	7	6	15	24+20 of the fourth cycle.
.....	6	5	15.5	Calice broken on side.
.....	9	7	18.5	24+20 of the fourth cycle.
.....	9.5	8.75	19	48, fourth cycle complete.
.....	[1] 10	[1] 9	25	48, four complete cycles.

[1] About.

e calice is oblique, its upper edge being considerably higher than wer. In the measurements given above the height of the coral- s measured from the tip of the pedicel to the highest point of the ilar margin.

e wall is only moderately thick, externally there is a variable nt of pellicular coating. Costae corresponding to all septa, t ct, but usually not prominent. There is a fair amount of varia- n the costal characters. In some specimens the costae of all s are equal or subequal, low, flattish or only slightly crested; ners, those corresponding to the septa of the first and second s of septa are decidedly more prominent than the intervening te. Those corresponding to the third cycle of septa may be ly more prominent than those corresponding to the fourth. times costae of both kinds are combined in one specimen. ter often in an intercostal space there is a raised thread or line i does not correspond to a septum. Minute, crowded granula- n are scattered over the surfaces of the costae and in the inter- t spaces.

Septa, thin, distant, those of the first and second cycles have slig exsert margins. In adult specimens, 19 to 25 mm. tall, there four complete cycles, in younger specimens the fourth cycle is complete. The members of the first and second cycles are of e size, extend to the columella, and are decidedly thicker than the o septa. The members of the fourth cycle are thinner and shorter those of the third. The septal margins are subentire, arched al and fall at a very steep angle to the bottom of the calicular f Septal faces finely striate, with more or less elongate granulat along the courses of the striae. Line of divergence of the striae close to the inner side of the wall. Wide, tall, thin, pali, rou above, stand before the septa of the third cycle, from whose i margin they are separated by a deep notch. The width of a pal about 1 mm., height, 1.5 mm.

Dissepimental endotheca, present, but not abundant. The sepiments thin.

The columella in fully grown specimens, prominent, compress even distinctly lamellar in appearance. In young and broken s mens it appears to be composed of interfused processes from inner ends of the septa, it is decidedly vesicular. Calice, r deep, 3 to 4 mm.

Localities and geologic occurrence.—Jamaica, Bowden, collecte J. B. Henderson and C. T. Simpson and R. T. Hill.

Costa Rica, "Colline en démolition," Limon, Costa Rica, No of H. Pittier's collection.

Cotypes.—Nos. 324815, 324816, U.S.N.M. (10 specimens).

The specimens from Limon, Costa Rica, are essentially dupli of those from Bowden. One specimen with a greater calicular eter of 9.5 mm. has a few quinary septa.

Genus STEPHANOCOENIA Milne Edwards and Haime.

1848. *Stephanocoenia* Milne Edwards and Haime, Comptes Rend., vol. 27,
1848. *Stephanocoenia* Milne Edwards and Haime, Ann. Sci. nat., Zool., vol. 10, p. 300.
1850. *Stephanocoenia* Milne Edwards and Haime, Mon. Brit. foss. Cor., p. XXX.
1857. *Stephanocoenia* Milne Edwards and Haime, Hist. nat. Corall., p. 264.
1884. *Antillastraea* Duncan, Linn. Soc. London Journ., Zool., vol. 28, p.

Type-species.—*Astrea intersepta* Lamarck = *Madrepora inte* Esper.

STEPHANOCOENIA INTERSEPTA (Esper).

1795. *Madrepora intersepta* Esper, Pflanzenth., Fortsetz., p. 99, pl. 79, fi
1816. *Astrea intersepta* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 2
1848. *Stephanocoenia intersepta* Milne Edwards and Haime, Comptes vol. 27, p. 469.

1848. *Stephanocoenia intersepta* Milne Edwards and Haime, Ann. Sci. nat., ser. 3, Zool., vol. 10, p. 300, pl. 7, figs. 1, 1*a*, 1*b*.
1848. *Stephanocoenia michelinii* Milne Edwards and Haime, Ann. Sci. nat., ser. 3, Zool., vol. 10, p. 301.
1864. *Plesiastraea spongiformis* Duncan, Geol. Soc. London Quart. Journ., vol. 20, p. 39, pl. 4, figs. 6*a*, 6*b*.
1866. *Stephanocoenia debilis* Duchassaing and Michelotti, Sup. Mém. Corall. Antilles, p. 76, pl. 9, figs. 7, 8.
1884. *Antillastraea spongiformis* Duncan, Linn. Soc. London, Journ., Zool., vol. 18, p. 108.
1895. *Stephanocoenia intersepta* Gregory, Geol. Soc. London Quart. Journ., vol. 51, p. 276.
1900. *Stephanocoenia intersepta* Vaughan, U. S. Geol. Surv. Mon. 39, pp. 152, 153.
1900. *Plesiastraea goodei* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 10, p. 553, pl. 67, fig. 1.
1901. *Stephanocoenia intersepta* Vaughan, Geol. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 20.
1902. *Plesiastraea goodei* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 106, fig. 1, p. 172, pl. 31 (not pl. 30 as given in the text), figs. 1, 1*a*.
1915. *Stephanocoenia intersepta* Vaughan, Carnegie Inst. Wash. Yearbook No. 13, p. 222.
1916. *Stephanocoenia intersepta* Vaughan, Carnegie Inst. Wash Yearbook No. 14, p. 221.

lthough the original description of Lamarck is brief, it is good. ording to him, "Cette espèce forme de large plaques un peu rexe, et offre à sa surface un réseau assez fin, constitué par les ls réunis des cellules. On voit un petit axe au centre de chaque e." He placed *Madrepora intersepta* Esper doubtfully in its nymy. Esper says regarding his specimens of the species: kommt diese Koralle von den ostindischen Meeren; ich habe sie hfalls durch die Güte des Herrn Prediger Chemnitz, mitgetheilt lten." It appears that Chemnitz had specimens from both the ntic and the Indo-Pacific and that he gave numbers of them to r. Apparently in some instances the locality labels were con- l, and that this is one of them, for Esper's figures (pl. 79, figs. are fairly good for the West Indian and Floridian species to h the specific name *intersepta* is now applied, and seem to me present no other living species of coral with which I am familiar. ie corallum is massive, either subhemispherical or pulvinate in r. The corallites are not protuberant, joined directly by their or by costae, in the latter case exothecal dissepiments may be nt. The diameter of the calices ranges between 2 and 3 mm. a in three cycles. Primaries and secondaries bear well-developed by which they are joined to the columella. Tertiaries thin and ively short. Septal margins subentire or very finely dentate. lnella, a compressed style of nearly the same height as the pali. othecal dissepiments subhorizontal, thin, average about 0.5 mm. .

As this is the type-species of the genus *Stephanocoenia*, the follow notes on its finer structure will be repeated, with slight emendati from my paper on the Eocene and lower Oligocene corals of United States (1900): The septa are composed of ascending trabe lae; near the wall is a line of divergence. External to this line trabeculae pass upward and have a slight inclination outward. trabeculae on the inner side of the line of divergence pass upward incline inward. The trabeculae are fine, measuring from 0.027 0.04 mm. across. A study of the lines of growth across the trabecu indicate an entire or very obscurely dentate septal margin. growth segments of the septa are well defined; the distance ac one measured along the line of divergence is about 0.32 mm. on average. The distal ends of the septa do not thicken sufficientl form a pseudotheca. In places dark centers or a dark band ca seen in the theca between the septal ends; that is, the wall bel in the cuthecal class. In some instances the wall is clearly for by peripherally placed dissepimenta. The corallites are rather o joined by their costae. In such instances the wall of one coralli usually formed by dissepiments. There is usually distinguishab central erect piece, around which the principal septa fuse by t inner margins. In some instances the columella appears to be for merely by the fusion of the septal margins. In one calice the of the columella is vacant, the septal margins having fused aroun The pali in cross section show as thickenings on the inner septal e The inner ends of the tertiary septa are free.

The above description should be compared with Felix's descrip of *Stephanocoenia formosa* (Goldfuss).[1] I should also like to attention to a statement by Miss Ogilvie, that "it is doubtful if (*Astrocoenia* and *Stephanocoenia*) are represented in recent sea She evidently did not know that the type-species of *Stephanoc* is the recent *S. intersepta* (Esper). So if there is any doubt, that the genus is found fossil earlier than late Tertiary.

It is astonishing to find the following statement in a recent p by Felix:[3] "Von dieser Art, welche heutzutage in Australis Meeren lebt, liegen mir zwei examplare vor. Fossil findet sich in Pliocänen Mergel von Rangoen auf Java." Such a statement the species he is discussing is one of the most widespread and known of those in Pleistocene deposits adjacent to and in the R waters of the western Atlantic Ocean, the Caribbean Sea, an Gulf of Mexico!

Synonymy.—Gregory in 1895 gave full references to the liter on this species up to that date, except that he did not place *Step coenia debilis* Duchassaing and Michelotti in its synonym.

[1] Deutsch. Geolog. Gesell. Zeitschr., vol. 50, pp. 252-254, pl. 2, fig. 1.
[2] Roy. Soc. London Trans., vol. 187, p. 307, 1896.
[3] Königl. Sächs Gesell. Wiss., Leipzig, Math. Phys. Kl., vol. 64, p. 444, 1912.

While in Turin in 1897 I examined the specimens identified by
chassaing and Michelotti as *Stephanocoenia intersepta* and *S. miche-*
. They belong to the same species. It is said of *S. debilis:* "Bien
les dimensions des calices de cette espèce soient les mêmes que
s la *Stephanocoenia michelini*, elle s'en distingue pourtant par la
raille, par les cloisons plus minces, et par les palis qui atteignent
auteur de la columelle." The only character of apparent value is
height of the pali, which are as tall as the columella. The pali
columella are usually of nearly the same height in the species;
reas on some specimens the columella is somewhat taller; in other
is the pali are taller.

examined Duncan's type of *Plesiastraea* [later described as *Antil-*
raea] *spongiformis* and a specimen identified by him as *Stephano-*
ia intersepta. The corallites of the former are united by their
ae, and where the costae meet there is often a second wall outside
true corallite wall. The second specimen had been cut, the larger
e bearing the label *Stephanocoenia intersepta;* the smaller piece,
h fits into the larger, was labeled *Plesiastraea spongiformis.*
can, it seems, could not distinguish between the two. I agree
Gregory in placing *Plesiastraea spongiformis* in the synonym of
hanocoenia intersepta.

lesiastraea goodei Verrill, fragment of the type No. 36497,
N.M., is precisely the same as *Stephanocoenia intersepta*—there
o differential characters.

istribution of Stephanocoenia intersepta.—Just how old, geolog-
, this species is, is not definitely known.

maica.—There is a specimen in the United States National
um bearing the station number 2580, which is for the collection
by Messrs. J. B. Henderson and C. T. Simpson in the Bowden
of Jamaica.

nto Domingo.—Miss C. J. Maury obtained five specimens of this
n-named species, as follows:

o Gurabo: Zone D, associated with *Stylophora affinis* Duncan,
acis decactis (Lyman), *Pocillopora crassoramosa* Duncan, *Orbicella*
ta (Duncan), *Orbicella cavernosa* var. *cylindrica* (Duncan), *Syzy-*
yllia dentata (Duncan); zone E, associated with *Placocyathus*
species, *Placocyathus variabilis* Duncan, *Stylophora* new species,
acis decactis (Lyman), *Syzygophyllia dentata* (Duncan), *Pavona*
species. Limestone, Los Quemados, associated with *Placocy-*
variabilis Duncan. As zones I and H of Miss Maury's sec-
epresent the Bowden fauna, zones E and D are stratigraphi-
above the Bowden.

a.—I collected a specimen near the Morro, at the mouth of
go Harbor, altitude about 240 feet above level. This specimen
pe of Pleistocene age. The general basement country rock is

Miocene limestone and marl, which contain some corals of reef fac and on this basement there are in places well-developed Pleistoc coral reefs. Therefore, the specimens of *Stephanocoenia inters* might be of Miocene age. Other specimens from stations 3436 3449, south side of the trocha in Santiago, seem definitely to bel in the La Cruz marl and to be of pre-Pleistocene age.

Doctor Pittier obtained a specimen of the species at the "Col en démolition," Limon, Costa Rica, apparently in association v *Asterosmilia hilli*, *Dichocoenia tuberosa*, and *Balanophyllia pitt* The horizon would therefore be near that of the Bowden marl.

Pleistocene.—General in the elevated reefs of the Caribbean Gulf region: Barbados (low-level reefs); Curaçao and Arube; Vaca, Florida.

Recent.—The West Indies in general, northward to the Bermu Florida; British Honduras.

Although I have often picked up specimens of this species w they had been washed up by the waves, both in Florida and in Bahamas, I have not certainly seen it alive on the reefs. As color of the living polyps is brown, while alive it so closely resem *Siderastrea radians* that only very close examination will disting between them, probably on the reefs it was mistaken for the la That it is a common associate of the usual West Indian reef c is shown by its usual presence among them in the fossil reefs. species ranges into slightly deeper water than most of the Indian reef corals. I dredged it at a depth of 4–9 fathoms off sau, Bahamas, and at a depth of 16 fathoms off Tortugas, Flo

Genus DICHOCOENIA Milne Edwards.

1848. *Dichocoenia* Milne Edwards and Haime, Compt. Rend., vol. 27, p
1857. *Dichocoenia* Milne Edwards and Haime, Hist. nat. Corall., vol. 2,
(type-species, figured, pl. DI, figs. 10*a*, 10*b*).
1917. *Dichocoenia* Vaughan, U. S. Geol. Surv. Prof. Pap. 98–T, p. 370.

Type species.—*Dichocoenia porcata* Milne Edwards and Hain

DICHOCOENIA TUBEROSA Duncan.

Plate 79, figs. 4, 4*a*, 4*b*.

1863. *Dichocoenia tuberosa* Duncan, Geol. Soc. London Quart. Journ., v
p. 432, pl. 15, figs. 5*a*, 5*b*.

This name has been placed in the synonymy of the living *L coenia stokesi* Milne Edwards and Haime by both Gregory [1] and self.[2] One-half of Duncan's type is in the United States Nat Museum, No. 155275, presented by the officers of the Geol Society of London. Although *D. tuberosa* is very similar t *stokesi*, *D. tuberosa* has a pendunculate base and granulate markings below the calicular surfaces in all the specimens I

[1] Geol. Soc. London Quart. Journ., vol. 51, p. 268, 1895.
[2] U. S. Geol. Survey Prof. Pap. 98–T, p. 371, 1917.

mined. As I am able to recognize the species I am treating it valid. Duncan records the form from the "Nivajè shale and aceous limestone of Santo Domingo."

Locality and geologic occurrence.—Costa Rica, "Colline, en démoli-n," Limon, No. 618 of H. Pittier collection, associated with *erosmilia hilli*, *Stephanocoenia intersepta*, and *Balanophyllia pittieri*. single, small, immature specimen. The illustrations present its racters well enough to make a detailed description unnecessary. anto Domingo, Rio Gurabo, zone F, of Miss C. J. Maury's sec-., associated with *Placocyathus variabilis* Duncan and *Antillia ia* (Duncan).

Genus EUSMILIA Milne Edwards and Haime.

1848. *Eusmilia* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 467.

Type-species.—*Madrepora fastigiata* Pallas.

EUSMILIA FASTIGIATA (Pallas).

1766. *Madrepora fastigiata* Pallas, Elench. Zooph., p. 301.
1895. *Eusmilia fastigiata* Gregory, Geol. Soc. London Quart. Journ., vol. 51, p. 260 (with synonymy).
1895. *Eusmilia knorri* Gregory, Geol. Soc. London Quart. Journ., vol. 51, p. 261 (with synonymy).
1901. *Eusmilia knorri* Vaughan, Geol. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 13.
1902. *Eusmilia aspera* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 114, fig. 3.
1915. *Eusmilia fastigiata* Vaughan, Washington Acad. Sci. Journ., vol. 5, p. 596.
1916. *Eusmilia fastigiata* Vaughan, Carnegie Inst. Washington Yearbook No. 14, p. 227.

tudy of large suites of *Eusmilia* convince me that *Eusmilia stigiata* (Pallas) and *E. aspera* (Dana) = *E. knorri* M. Edwards and ane are not specially separable, as there is great variation and plete overlapping in the columellar characters by which they e distinguished.

calities and geologic occurrence.—Canal Zone, Pleistocene at sta-on 5849, Mount Hope; Costa Rica, 6251, Monkey Point, collected y H. F. MacDonald.

neral in the living and Pleistocene coral reefs of Florida, the Indies, and the Caribbean coast of Central America.

Family ASTRANGIIDÆ Verrill.

Genus CLADOCORA Ehrenberg.

1834. *Cladocora* Ehrenberg, Corallenth. Roth. Meer., p. 85 (of separate).
1848. *Cladocora* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 493.

Type-species.—*Caryophyllia cespitosa* Lamarck.

CLADOCORA ARBUSCULA (Le Sueur).

1820. *Caryophyllia arbuscula* Le Sueur, Paris Mus. Mém., vol. 6, p. 275, p
figs. 2*a*–2*d*.
1901. *Cladocora arbuscula* Vaughan, U. S. Fish Commission Bull. for 1900, v
p. 298, pl. 2, figs. 3, 3*a* (with synonymy).

This species is common in the Pleistocene marls near Colon.

Locality and geologic occurrence.—Canal Zone, station 5850
6039, Pleistocene, Mount Hope, collected by D. F. MacDon
Living in Florida and the West Indies on reef flats and in water f
8 or 9 to about 20 fathoms deep.

Family ORBICELLIDAE Vaughan.

Genus ORBICELLA Dana.

1846. *Orbicella* Dana, U. S. Expl. Exped. Zooph., p. 205.
1849. *Phyllocoenia* Milne Edwards and Haime, Comptes Rend., vol. 27, p
1901. *Orbicella* Vaughan, Geol. Reichs Mus. Leiden Samml., ser. 2, vol. 2,
1902. *Orbicella* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 93.
1918. *Orbicella* Vaughan, Carnegie Inst. Washington Pub. 213, p. 85.

Type-species.—*Madrepora annularis* Ellis and Solander.

Of this perplexing genus of corals, the following species and v
ties are treated as valid in the present papers:

Orbicella annularis (Ellis and Solander).
limbata (Duncan).
imperatoris, new species.
altissima (Duncan).
antillarum (Duncan).
cavernosa (Linnaeus).
var. *endothecata* (Duncan).
var. *cylindrica* (Duncan).
aperta (Verrill).
bainbridgensis, new species.
costata (Duncan).
canalis, new species.
tampäensis, new species.
var. *silecensis*, new variety
brevis (Duncan).
insignis (Duncan).
intermedia (Duncan).
gabbi, new species.

As synonymy is discussed on subsequent pages, it is here
necessary to say that under the name *Astraea megalaxona*[1] Du
described from Antigua a silicified coral which is not determin
that his *Astraea crassolamellata*[2] and its varieties are here referr

[1] Geol. Soc. London Quart. Journ., vol. 19, p. 120, pl. 13, figs. 12*a*, 12*b*, 1863.
[2] Idem., p. 412, pl. 13, figs. 1–7.

fungid genus *Diploastrea* Matthai; his *Astraea cellulosa*[1] is made type-species of a new genus, *Antiguastrea*, and his *Astraea antinsis*[2] and *Astraea tenuis*[3] are referred to the fungid genus *thomorpha* Reuss.

lthough inadequacy of information regarding four species, *O. ssima*, *O. antillarum*, *O. insignis*, and *O. intermedia*, described by ican, renders the preparation of an adequate synoptic table racticable, an attempt will be made to summarize the most king characters. With one exception, the species fall into two er groups: the members of the first group normally have only e cycles of septa; those of the second group have four cycles, fourth cycle is incomplete in some specimens, while in other specis a variable number of quinary septa are present. One species, *cella gabbi* Vaughan, has five cycles of septa.

SYNOPSIS OF AMERICAN SPECIES OF ORBICELLA.

Species with 3 cycles of septa.

les usually 2 to 3 mm. in diameter; costae subequal; primary and secondary septa qual, extend to the columella..... 1. *O. annularis* (Ellis and Solander).

les 3 to 4 mm. in diameter; costae usually alternately large and small; secondary epta thinner than the primaries, but usually reach the columella
2. *O. limbata* (Duncan).

les 3.5 to 5 mm. in diameter; costae prominent, thin; secondary septa usually bout half as long as the primaries, tertiaries small and thin.
3. *O. imperatoris*, new species.

les 7.5 mm. in diameter; costae tolerably developed, subequal; primary and secndary septa subequal, extend to the columella... 4. *O. antillarum* (Duncan).

Species of Orbicella with the 4th cycle of septa nearly or quite complete.

les 5 mm. in diameter; costae unequal, thicker than the septa, last "order" of ostae well developed, contrasting with rudimentary septa; septa irregular in rrangement, *36 in number, 6 septa in each of 6 systems*.. 5. *O. altissima* (Duncan).

les from 5 to 11 mm. in diameter; costae correspond to all septa, usually subequal; epta normally in 4 complete cycles, subequal over top of wall, first 3 cycles reach olumella, no pali..... 6. *O. cavernosa* (Linnaeus).
Costae strongly alternating in size, fourth cycle small and thin without obvious corresponding septa..... 6*a*. var. *endothecata* (Duncan).
Corallites smaller than in 6*a* (5 to 6 mm. in diameter), about 38 septa, last cycle of costae rudimentary or obsolete.... 6*b*. var. *cylindrica* (Duncan).

mar to *O. cavernosa* except that the first three cycles of septa are thinner and aller, strongly contrast in height with the quaternaries.. 7. *O. aperta* (Verrill).

les 6 to 7 mm. in diameter; costae low, equal; septa low and subequal on mural mmit; primaries and secondaries with rather wide erect, paliform lobes, youngt septa composed of incompletely fused spines.
8. *O. bainbridgensis*, new species.

les 7.5 to 8.5 mm. in diameter; costae highly developed, alternate in size except calicular margin; septa normally in 4 cycles, thin except in wall of some specens, paliform lobes and thickenings distinct but rather small, tertiaries usually orter than secondaries..... 9. *O. costata* (Duncan).

[1] eol. Soc. London Quart. Journ., vol. 19, p. 417, pl. 13, fig. 10. [2] Idem, p. 419, pl. 13, fig. 8.
[3] Idem, p. 421, pl. 13, fig. 11.

Calices 5 to 9 mm. in diameter; costae subequal or alternately large and small b
calicular edge. Septa in 4 or nearly 4 complete cycles; primaries as a rule not
larger than the secondaries, with a prominent tooth on inner end; second
smaller, but with paliform tooth on inner end of each; tertiaries still sma
quaternaries very small..... 10. *O. canalis*, new spe

Calices 6 to 10 mm. in diameter, exsert 4 to 4.5 mm.; costae very prominent, r
only rudimentary costae correspond to last cycle of septa; septa in 3 or 4 s
margins of primaries exsert as much as 1.5 mm... 11. *O. tampäensiss*, new spe

Calices not so elevated as in 11; small but distinct costae correspond to
cycle of septa..... 11*a*. var. *silecensis*, new var

Calices 5 mm. in diameter, protuberant but rather low; costae strongly alterna
in size; primary septa the largest; fourth cycle incomplete
12. *O. brevis* (Dun

Calices 10 mm. in diameter; costae long, slender, subequal, occasionally a rudimen
costa with no corresponding septum; septa delicate, long, slender, distant, fo
cycle incomplete..... 13. *O. insignis* (Dun

Calices 5 mm. in diameter; in places small costae between larger ones; a few
ternary septa..... 14. *O. intermedia* (Dun

The numbers preceding the names in the synopsis correspon
numbers before the names heading the following descriptions.

As *Orbicella gabbi* is the only species with 5 complete cycle of se
it needs no special caption nor is *O. irradians* included in the ke

1. ORBICELLA ANNULARIS (Ellis and Solander).

Plate 80, figs. 7, 7*a*, 7*b;* plate 81, figs. 1, 1*a*, 2; plate 82, figs. 1, 1*a*, 2; plate 83
1, 2, 3, 3*a;* plate 84, figs. 1, 2, 3, 3*a*.

1786. *Madrepora annularis* Ellis and Solander, Nat. Hist. Zooph., p. 169, p
figs. 1, 2.

1786. *Madrepora faveolata* Ellis and Solander, Nat. Hist. Zooph., p. 166, p
figs. 5, 6.

1790. *Madrepora acropora* Gmelin, Linn. Syst. Nat., ed. 13, p. 3767.

1790. *Madrepora faveolata* Gmelin, Linn. Syst. Nat., ed. 13, p. 3769.

1794. *Madrepora acropora* Esper, Pflanzenth., Fortsetz., vol. 1, p. 21, pl. 3

1816. *Astrea annularis* Lamarck, Hist. nat. Anim. s. Vert., vol. 2, p. 259.

1821. *Astrea annularis* Lamouroux, Exp. Méth. Genres des Polyp., p. 58, p
figs. 1, 2.

1821. *Astrea faveolata* Lamouroux, Exp. Méth. Genres des Polyp., p. 58, p
figs. 5, 6.

1834. *Explanaria annularis* Ehrenberg, Corallenth. Roth. Meer., p.
separate).

1846. *Astraea* (*Orbicella*) *annularis* Dana, U. S. Expl. Exp. Zoophytes, p
pl. 10, fig. 6.

1857. *Heliastraea annularis* Milne Edwards and Haime, Hist. nat. Corall
2, p. 473.

1861. *Heliastraea annularis* Duchassaing and Michelotti, Mém. Corall. An
p. 76 (of reprint).

1861. *Heliastraea acropora* Duchassaing and Michelotti, Mém. Corall. An
p. 76 (of reprint).

1861. *Heliastraea lamarcki* Duchassaing and Michelotti, Mém. Corall. An
p. 76 (of reprint).

1863. *Cyphastraea costata* (part) Duncan, Geol. Soc. Lond. Quart. Journ., v
pp. 441 and 443.

1863. *Astraea barbadensis* Duncan, Geol. Soc. Lond. Quart. Journ., vol. 1 pp
421 and 444, pl. 15, figs. 6*a*, 6*b*.

1864. *Orbicella annularis* VERRILL, Mus. Comp. Zool. Bull., vol. 1, No. 3, p. 48.
1865. *Orbicella annularis* VERRILL, Boston Soc. Nat. Hist. Proc., vol. 10, p. 323.
1866. *Heliastraea annularis* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 84 (of reprint).
1866. *Heliastraea lamarcki* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 84 (of reprint).
1866. *Heliastraea acropora* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 84 (of reprint).
1866. *Heliastraea barbadensis* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 85 (of reprint).
1866. *Cyphastraea costata* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 85 (of reprint).
1868. *Heliastraea barbadensis* DUNCAN, Geol. Soc. Lond. Quart. Journ., vol. 24, p. 24.
1868. *Cyphastraea costata* DUNCAN, Geol. Soc. Lond. Quart. Journ., vol. 24, p. 24.
1895. *Orbicella acropora* GREGORY, Geol. Soc. Lond. Quart. Journ., vol. 51, p. 272.
1895. *Cyphastraea costata* GREGORY, Geol. Soc. Lond. Quart. Journ., vol. 51, p. 274.
1895. *Echinopora franski* GREGORY, Geol. Soc. Lond. Quart. Journ., vol. 51, p. 274, pl. 11, figs. 2*a*, 2*b*.
1901. *Orbicella acropora* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 22.
1901. *Orbicella acropora* VAUGHAN, U. S. Fish Commission Bull. for 1900, vol. 2, p. 301, pls. 6, 8.
1902. *Orbicella annularis* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 94, pl. 15, fig. 1.
1902. *Orbicella annularis* var. *stellulata* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 96, pl. 15, fig. 2.
1902. *Orbicella hispidula* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 100, pl. 15, figs. 3, 3*a*, 3*b*.
1902. *Orbicella annularis* VAUGHAN, Biol. Soc. Washington Proc., vol. 15, p. 56.
1903. *Orbicella annularis* DUERDEN, Nat. Acad. Sci. Mem., vol. 8, p. 564, pls. 8–10, figs. 64–73.
1915. *Orbicella annularis* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 596.
1916. *Orbicella annularis* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, p. 227.

ubsequent study has led me to believe that changes should be
nde in the synonymy as given in the first of my papers cited in the
ynonymy. *Phyllocoenia limbata* Duncan, *P. limbata* var. *tegula*
)uncan, and *Plesiastraea ramea* Duncan represent one species and it
s separable from *Orbicella annularis*. As *Phyllocoenia limbata* is the
der name, the species should be designated *Orbicella limbata* (Dun-
ca). The most conspicuous difference between it and *O. annularis*
consists in its primary septa being markedly more developed than
th secondaries.

rbicella annularis is the principal coral of the outer reefs in Florida,
th West Indies, and on the Caribbean side of Central America. It
s eneral in the elevated Pleistocene of the same region.

rof. J. Graham Kerr, of the University of Glasgow, has kindly
ie me photographs of the type of this species, which is preserved

in the Hunterian Museum at that institution, and I have based t following description on them:

The corallum is head-shaped, with a greater diameter of 107 m and a lesser of 86.

The calices are circular, 2 mm. in diameter, margins slightly e vated, joined by equal costae, distance apart usually about 1 m occasionally 2.

Septa 24 in number, alternately larger and smaller; the larger rather thick and reach the columella; the intermediate ones are sh and their inner ends are free.

Columella spongy, well developed, its diameter about one-th that of the calice.

A comparison of the photographs with specimens shows that traditional *Orbicella annularis* of the Caribbean and Gulf regio correctly identified.

There are in the collection of the United States National Muse a number of specimens that are almost duplicates of the type-sp i- men, except that they are not worn, as is the type. These specim form the basis of the succeeding description (see pl. 81, figs. 1, 1*a*

The corallum forms rounded masses rising above a rather la e, firmly attached base, which is, however, less in diameter than maximum diameter of the corallum. Frequently there is a p- jecting or incrusting edge whose lower surface is covered by epith a. The upper surface may be uniformly rounded, undulate, or lob d. The size, of course, is variable; the masses may be several fee in diameter.

The calices are circular, or slightly deformed. Their diame r, measured between thecal summits is from 2 to 2.5 mm. In dep s- sions on the surface they may be smaller, about 1.5 mm., but t se are abnormal. Their edges are from 0.5 to almost 2 mm. ap t. about 1 mm. is probably an average. The calicular edges re slightly elevated. The intercorallite areas are costate. Costae r- respond to all septa; subequal or alternating in size, those of adj n- ing calices meeting; edges dentate; thicker than the width of he intercostal spaces and moderately elevated.

Septa in three complete cycles, primaries and secondaries eq al, rather stout, extending to the columella and fusing to it; tertia es shorter, about half the length of the primaries, somewhat thin r. inner edges free. Margins of the primaries and secondaries d d- edly exsert; their inner edges fall perpendicularly to the botto of the calicular fossa, and bear just above the columella one or tw prominent teeth, with a few smaller teeth above; the septal ar is either very gentle, obtuse, or it may be truncate, its dentations ne the outer margins steep, but more inclined than the inner, dentat ns relatively coarse. Septal faces finely granulate; in longitud al sections, the inner edges are lacerate, the last cycle with perforat ns.

Endothecal dissepiments delicate, thin, nearly horizontal, slightly inclined downward from the corallite walls. In this series of specimens the corallite walls are thick and close together, those of adjacent corallies sometimes being solidly fused together; usually, however, there is some exotheca, consisting of stout, subhorizontal dissepiments.

Columella well developed, formed by interlacing processes from the inner edges of the septa; diameter from one-third to one-half that of the calice; its upper surfce about 1 mm. below the thecal margin.

These specimens, it should be repeated, are typical, and except in size and to a certain extent in the configuration of the surface show almost no variation. They come from the following localities: Dry Tortugas, Florida, Dr. Edward Palmer, collector, 8 specimens; east end of Hog Island, Bahamas, B. A. Bean, collector, 1 specimen; Florida and the Bahamas, many specimens, collected by T. W. Vaughan and others. There are other specimens, bearing the indefinite label "West Indies" or having no locality stated. These localities indicate that the species in its typical form is of general occurrence in the coral reef areas around the Caribbean Sea and Gulf of Mexico.

The recent specimens in the United States National Museum show at least four kinds of variation from the typical form.

Variation No. 1 (pl. 84, fig. 2).—This variation is, I believe, only a growth form. It, in its structural features, is the same as the typical form, except that the septa near the growing edge are less exert and the exotheca appears to be absolutely solid. The corallum is an obtuse, compressed column, with an undulated surface. Greater diameter of the base, 62 mm.; lesser 52 mm.; height 72 mm.

Locality.—Dry Tortugas, Florida.

Variation No. 2 (pl. 81, fig. 2).—The general growth form is similar to that of typical specimens, except that the surface is thrown into gibbosities of irregular shape and size; these are often about a centimeter in height and several centimeters in diameter. The calices are larger than in the typical specimens, often measuring 3, occasionally 4 millimeters in diameter, between thecal summits. The thecal edges are slightly elevated; the margins of the primaries and secondaries decidedly exsert, not infrequently standing 2 mm. above the intercorallite furrow. The three characters here mentioned are the distinguishing ones of this variation, namely, gibbosities on the surface; larger calices; and more exsert septa.

Localities.—Dry Tortugas, Florida, Dr. Edward Palmer, collector, 1 specimen; east end of Hog Island, Bahamas, B. A. Bean, collector, 1 specimen; and two other specimens, without locality labels.

Variation No. 3 (pl. 82, fig. 2) is represented by a single specime
The corallum is discoid, lower surface flat, upper surface convex, so
irregularities. Greater diameter, 22.7 cm., lesser, 19.2 cm; thickn
in the center about 5 cm., on the edge, 3 cm.

Calices with elevated margins and crowded together, the differ
corallite walls almost contiguous; margins of primary and second
septa decidedly exsert. Diameter of calices about 2.75 mm.

The distinguishing characters of this variation are its discoid fo
its crowded calices, its decidedly exsert septal margins.

Locality.—Fort Taylor, Key West, Florida.

Variation No. 4 (pl. 82, figs. 1, 1*a*) is represented by the sp
mens that I have described from Mayaguez, Porto Rico, in
"Stony corals of the Porto Rican waters."[1] The following desc
tion is based on them:

The corallum forms ascending masses; the largest specimen
about 20 cm. tall; diameter above flared-out base about 13.5
The base of each specimen is considerably produced as a wide,
edge invested below by epitheca.

Calices with very slightly or only moderately elevated marg
diameter measured between thecal summits, from 3.25 to 4 m
rather shallow; distance apart, from a thin dividing edge to .5
mm.; about 1.5 mm. is probably the average. Thin costae mo
ately prominent, subequal, or alternating in size, correspond t
septa; those from one calice extend across the intercorallite sp
and meet those from the adjacent calices.

Septa thin, 24 to 28 in number, one-half of them extend from
wall to the columella, and have decidedly exsert margins; the o
half are not so tall and are short, their inner ends free.

Endotheca and exotheca as in the typical specimens, except
they are more delicate.

These differ from typical specimens by their much lighter tex
which, of course, is determined by their thinner skeletal struct
the wide, flaring, free edges of the base, and their larger cal
The calices overlap in size those of variation No. 2, otherwi
should consider the specimens as representing a distinct species.

Variation No. 5 (pl. 83, figs. 1, 3, 3*a*).—*Orbicella hispidula* Ver
The following is the original description:

> Coral an incrusting mass over 125 mm. across, and from 5 to 20 mm. thick. The texture is rather solid and heavy, there being much solid exotheca betwee the calicles, which are rather far apart, the interspaces being mostly equal to, and ten exceeding, their diameter.
>
> The calicles are round, regularly stellate, a little prominent, with swollen, sl ng costate rims much as in those of *O. annularis*, which they resemble in size, t ugh distinctly larger. The septa are in three very regular cycles; the twelve pri pal

[1] Bull. U. S. Fish Commission for 1900, vol. 2, p. 301, pls. 6, 7, 1901.
[2] Conn. Acad. Arts and Sci. Trans., vol. 11, pp. 100, pl. 15, figs. 3, 3*a*, 3*b*.

s are wide, nearly equal, all reaching the rather large columella; their edges are pendicular and finely, sharply serrate, with slender, rough teeth, which extend over their prominent, obtuse, or subtruncate summits, giving them a rough earance under a lens; their surfaces are also rough or hispid with numerous conical ns. The septa of the third cycle are narrow, straight, and usually reach about fway to the columella.

e costae are thick, not very high, meeting or inosculating between the calicles, covered with a single row of small slender, rough spinules. The columella is l developed, formed of contorted trabecular processes, and often having a small in the center and a few erect spinules, similar to the slender, rough, paliform teeth t often (but not regularly) stand at the base of some of the 12 larger septa.

a sections the walls are very thick and nearly solid. The endothecal dissepits are small, thin, irregularly convex or flat above. The calicles are not filled below, or only slightly encroached upon, by a deposit between some of the septa. meter of the calicles 3 to 3.5 mm.; distance between them mostly 2 to 4 mm., n more.

lorida Reefs (Maj. E. B. Hunt), Yale Museum, No. 98. Near Nassau, N. P. (l. R. P. Whitfield), Amer. Mus., New York.

his has the general appearance of *O. annularis*, but with calicles larger than usual decidedly farther apart. The walls and exotheca are much thicker and more l, and the endothecal cells are fewer and less regular. The sharply spinulose hispid septa and costae are also characteristic. The exothecal deposits are dly as solid as in *Oculina*.

Nassau specimen, in the American Museum, is an irregular, rounded mass about 5 ches in diameter, and 3 to 4 thick, with a a lobulated surface. The coral is heavy solid; the surface of the coenenchyma is spinulose; the costae well developed. T calicles are more variable in size than in the type, in some places being one-half ller and closely crowded. Coll. R. P. Whitfield.

The form of *O. hispidula* Verrill, in which the upper surface is lobulate, is common on the reef off Cocoanut Point, Andros Island, Bahamas, where a suite of 12 specimens was obtained by the *Anton Dohrn* expedition in 1914. The calices of most of these specimens are precisely as in the type of Professor Verrill's *O. hispidula* (fragment of type No. 40476, U.S.N.M.) and Gregory's *Echinopora franski* (fragment of type No. 156455, U.S.N.M.), but in both growth form and calicular characters there is intergradation with the more typical characters of *O. annularis*. Plate 76, figures 3, 3*a* illustrates the appearance of one of the specimens with lobulate surface.

A specimen from Port Castries, Santa Lucia (pl. 83, fig. 2), shows a variation worthy of note. In all of the variations so far described, the primary and secondary septa are constantly subequal, uniformly reaching the columella. In the Santa Lucia specimen a secondary septum in some systems is shorter and thinner than a primary; and in some calices there are as many as 30 septa. This specimen is of importance for comparison with *Phyllocoenia sculpta* var. *tegula* Duncan and *Echinopora franksi* Gregory.

These remarks cover the variation of the recent specimens that I have actually been able to study. Pourtalès, Verrill, and Duerden, however, have added other observations.

Pourtalès says of the species:

The same remarks about variation, given under the head of *O. cavernosa*, can applied to this species; there are very fine examples in the museum of the g variation of form of the calicles in the same specimen.

It is very common in Florida on the reef and in the channels, and forms l hemispherical masses nearly up to low-water mark. The central and highest often dies out from being left uncovered at very low tide and the mass then assu an annular form through the decay of the dead part.[1]

Verrill writes:

It shows considerable variation in the size of the calicles; in the extent to wh they are crowded together; in the prominence of their borders above the interver exotheca; in the prominence of the septa above the walls; and in the extent to wh the small septa of the third cycle are developed. But yet these variations, so fa I have seen, never go so far as to render difficult the recognition of the species un the specimens are badly worn.

* * * * * * *

When well grown it forms hemispherical or spheroidal masses, up to 5 feet or m in diameter. But it also grows in irregular incrusting plates, and sometimes in no or lobulate masses, or even in branched forms.[2]

Duerden, in describing specimens from Jamaica, says:

The species occurs on coral areas in small or large, fixed, nearly spheroidal ma also as an incrustation occupying areas several feet across. Small isolated colo are sometimes conical. In places it is an important constituent of the reefs.[3]

This is one of the species to which I devoted a great d attention in my study of the living reefs in Florida and the Bahan and have inserted references to two of my papers (1915, 1916) in wh it is considered. It is preeminently the great reef-building spe of the Pleistocene and Recent reefs in Florida and the West Ind Where there is sand on the bottom, it forms tall, thick, round-top columns.

VARIATION OF FOSSIL SPECIMENS.

There are specimens, particularly those of known Pleistocene a similar to the typical form of the species, except that there may b variations in the size of the calices; those of a specimen from Ir Nassau, Curaçao, range from 3 to 4.5 mm. in diameter, measu between thecal summits; those of another specimen from Wt punt, Curaçao, are from 2.5 to 3 mm. in diameter. The for possesses the largest calices of any specimen of the species I have s

The variations not included in the preceding remarks may b divided into two classes, dependent upon growth—namely, *a*, e planate or incrusting; *b*, columnar.

A. Growth from explanate or incrusting.

[1] Mus. Comp. Zool. Ill. Cat. No. 4, p. 72, 1871.

[2] Conn. Acad. Arts and Sci. Trans., vol. 11, pp. 95, 96, 1902.

[3] West Indian Madreporarian Polyps, Nat. Acad. Sci. Mem., vol. 8, p. 561, 1903.

Gregory[1] was mistaken in referring the specimens described by
m as *Echinopora franksi* (see pl. 84, fig. 4) to the genus *Echinopora*.
e following is the original description:

Diagnosis.—The coral has a broad base; from this pass outward short, thick, rapidly
ering expansions.
orallites long, often an inch in length. Their distance one from the other varies
n half their diameter to the whole.
epta strongly dentate; inner teeth paliform, in three cycles. Those of the first
le always unite to the columella; those of the second cycle often do so, but may
the primary septa; those of the third cycle are much smaller and independent,
a few may unite with the septa of the other orders.
olumella of very loose tissue; half the diameter of the corallite. Endotheca scanty.
nenchyma thinner than in other species of the genus. Echinulations of the surface
rse. Epitheca thick and well developed.
Dimensions.—Diameter of an average corallite, 3 mm.; height of corallite varies
a 10 to to 25 mm.; thickness of wall varies from 1½ to 3 mm.
Distribution. Recent: West Indies. *Fossil:* Barbados: Lowlevel Reefs, near
dgetown.

Cotypes.—British Museum (Natural History); a piece of one of
cotypes in the United States National Museum, No. 156,455.

A comparison of this description with the notes on the variation
Orbicella annularis will show that it presents no important differ-
e from variations of the species already recorded. Its growth
m is explanate, the exotheca is solid, and the secondary septa
en, but not always, reach the columella.

3. Growth from columnar (pl. 84, figs. 3, 3*a*.)

These are the specimens referred to in my paper "Some fossil
als from the elevated reefs of Curaçao, Arube, and Bonaire,"[2]
ained by Mr. v. Koolwijk at Westpunt, Curaçao. Three of the
cimens are in the United States National Museum, and they
m the basis of the following description:

The corallum forms ascending, compressed, obtuse columns.

Dimensions in millimeters of variant of Orbicella annularis from Curaçao.

ecimen No.	Greater diameter of base.	Lesser diameter of base.	Height.	Remarks.
	mm.	*mm.*	*mm.*	
	37.5	25	60	Bifurcation 32 mm. above base.
	30+	23	71	Constricted above base; gradually enlarging above the constriction.
	27.5	21	91	Figured, pl. 84, figs. 3, 3*a*.

alices 2.5 to 3.5 mm. in diameter; from less than 1 mm. to 2 mm.
rt. The upper margin is usually not elevated, while the lower
is, thus tilting the calicular orifices. The maximum length of
l lower limb of the calice is about 3 mm. Subequal, relatively
k, dentate costae correspond to all septa.

[1] Geol. Soc. London Quart. Jour., vol. 51, p. 274, pl. 11, figs. 2*a*, 2*b*, 1895.
[2] Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, Heft I, p. 26.

The usual number of septa is three complete cycles; primaries a
secondaries subequal, reach the columella; tertiaries short, inr
edges free. The septa present only one noteworthy difference fr
what is usual in *O. annularis;* that is, the margins of the primar
and secondaries are less exsert.

Columella not very large, loose, trabecular.

The three salient characteristics of this variant are (1), its grow
form; (2), the tilted calices; (3), the lower (less exsert) margins
the primary and secondary septa.

Geologic horizon.—Pleistocene.

NOTES ON SYNONYMY.

A number of other names need to be considered in greater or l
detail.

Gregory [1] applied the name *Orbicella acropora* (Linnaeus) to t
species. He accepted the determination of the species by Mi
Edwards and Haime,[2] who separated it from *O. annularis* by
having no septa corresponding to the last cycle of costae. Greg
showed that occasionally in typical specimens of *O. annularis*
last cycle of septa may be absent while the costae are present, t
breaking down the character used by Milne Edwards and Haime
distinguish the species. I accepted Gregory's conclusion,
followed him in my paper on Some fossil corals from the eleva
reefs of Curaçao, Arube, and Bonaire, and subsequent pap
Professor Verrill, in his Variations and Nomenclature of Bermud
West Indian, and Brazilian reef corals,[3] declares that *Madrep*
acropora Linnaeus "is utterly indeterminable," and takes the n
later specific name, *annularis* Ellis and Solander, for the spec
Subsequent study convinced me that Professor Verrill is right,
I published my change of opinion in a paper on Some recent Char
in the Nomenclature of West Indian corals.[4] Therefore, I
believe that *Madrepora acropora* Linnaeus should be considere
undeterminable and that the name should be dropped from c
nomenclature.

The type-specimen of *Madrepora faveolata* Ellis and Solande
preserved in the Hunterian Museum of the University of Glasg
where I have seen it, and Prof. Graham Kerr has kindly sent
photograph. It is a worn specimen, considerably infiltrated
calcium carbonate, and is probably the same as *Orbicella annul*

Astraea (*Orbicella*) *stellulata* Dana has been carefully redescribe
Professor Verrill from Dana's types, which are preserved in the
University Museum. The following is his description:

They [5] are beach-worn specimens of a true *Orbicella*, more or less infiltrated
calcium carbonate, to which the unusual solidity of the walls and exotheca, in

[1] Geol. Soc. London Quart. Journ., vol. 51, p. 272, 1895.
[2] Hist. nat. Corall., vol. 2, p. 477 1857.
[3] Conn. Acad. Arts and Sci. Trans., vol. 11, p. 94, 1902.
[4] Biol. Soc. Washington Proc., vol. 15, p. 56, 1902.
[5] Conn. Acad. Arts and Sci. Trans., vol. 11, p. 96, pl. 15 ,fig. 2, 1902.

ps, as seen in sections figured by Dana, seem to be partly due. In other parts the st cture is nearly as in *O. annularis*, to which it probably belongs, though there are d erences in the sections not due to infiltration. Its septal arrangement is the same en ordinary specimens of the latter, those of the third cycle being distinct, but n ow and thin. The borders of the calicles seem to have been but little raised, and th septa rather thinner than usual, and not much exsert, but the poor condition of th specimens renders these characters rather uncertain.

he calicles are rather smaller (2 to 2.5 mm. in diameter) than is usual in *O. annu-la*. The thin septa are in three regular cycles; those of the third cycle are very th and reach only one-fourth or one-third to the columella, which is well developed. T septa are a little thickened at the wall; their faces are only slightly granulated. T re are a few, irregular, small teeth on their inner edges where best preserved; in er ends are all worn off; some have a paliform tooth at the base. The costae are w developed, inosculating, with irregular exothecal dissepiments between them, as in *O. annularis*. But in some vertical sections the walls appear as narrow, solid st ctures (where unaltered); in the sections the columella region is loosely filled wi stout ascending trabeculae; the endotheca consists of small, very thin, nearly ho zontal dissepiments, inclining downward a little, and often in two series. No. 42.

heir origin is uncertain, but it appears to be West Indian. They are in the same be h-worn state as several other types of West Indian corals studied by Professor D a. Apparently most West Indian corals, in good condition, were scarce in A erican museums at the time when he wrote his great work.

appears to be a small or somewhat dwarfed variety of *O. annularis*. I have seen fe specimens of a similar variety from the Florida reefs.

his may well be identical with *M. stellulata* Ellis and Solander, but the latter ca not be determined with any certainty from the figure, which represents a badly wo specimen. Its calicles, as figured, are mostly even smaller than in Dana's type, an somewhat unequal in size; the walls appear to be as solid as in the latter; the ca les project slightly as in *annularis;* 12 to 15 septa are figured, all perfect; colu-m a is as in *annularis*. There is much more reason for calling this a variety of *O. an ularis* than there is for identifying it with *Solenastraea hyades*, as Gregory has done. Th e is no evidence that it is a *Solenastraea*.

Fortunately Dana's *Orbicella stellulata* is a synonym of *O. annu-la* s and is not even of varietal importance. Professor Verrill says, "his may well be identical with *M. stellulata* Ellis and Solander," an opinion from which I emphatically dissent. The figures of Ellis an Solander are of a *Solenastrea* (Nat. Hist. Zooph., pl. 53, figs. 3, 4); th costae do not continue from one calice to those of adjacent calices, an the exotheca, as is shown by the side of figure 3, is typical of *So nastrea*. Furthermore, in the description of the species it is st ted, "interstitiis planiusculis scabriusculis," the intercorallite ar s are not "radiate" as in *annularis*. The *Heliastraea stellulata* of Milne Edwards and Haime (see pl. 80, figs. 7, 7*a*, 7*b*) is not the *Millepora stellulata* of Ellis and Solander; it is probably the same as *Orbicella annularis*.

There is much doubt about the *Cyphastraea oblita* Duchassaing and Michelotti. The following is the original description:

Espèce arrondie, avec des étoiles arrondies et à bord un peu elévé: côtes rares, pr que confluentes; les intervalles de l'une à l'autre étoile sont garnies de granu-lat ns; la columelle est grande et papilleuse.

La *Cyphastrea oblita* a les bords moins elévés, et les cloisons plus debordante qu celles de la *Cyph. microphthalma* qui sont aussi garnies d'une petite dent sul al forme qui manque dans la *Cyph. oblita.* St. Thomas.

I found in the Museum of Natural History at Turin a speci e labeled "*Cyphastrea oblita.*" It is a specimen of *Orbicella annul ri* Another specimen bearing the same label, seen in the Muséum d is toire Naturelle at Paris, is a *Solenastrea.*[1] The latter is a rou le head with a greater diameter of about 130 mm. The calices r g in diameter from 2 to 3 mm.; distance apart from somewhat le s slightly more than 1 mm., occasionally 2 mm. Margins of the ca e marked by a slightly raised rim. Costae insignificant, occasio ll extending from one calice to the next. Septa in three com et cycles, primaries and secondaries reaching the columella; terti ie shorter, with inner edges free, i. e., not fused to the sides of a l ve cycle. Pali variable in development; in some calices they are l ge flattened above, before all septa except the last cycle; in ot rs several teeth indicate the position of a palus. Columella, lax n papillary. This specimen is the same as the *Heliastraea a id* Duchassaing and Michelotti.

The original description of *Cyphastrea oblita* is not adequate fo identification. One of the specimens from the Duchassaing n Michelotti collection is *Orbicella annularis,* the other the same is ei own *Heliastraea abdita.* Because the Paris specimen is probably h type I am placing the species in the synonymy of *Solenastrea l r noni* M. Edwards and Haime (see p. 400).

Heliastraea rotulosa Duchassing and Michelotti is a growth for o *O. annularis,* judging by the description. I did not find the ty in Turin.

The specimens determined by Duchassing and Michelott a *Heliastraea acropora* (Linnaeus) and *H. lamarcki* Milne Edwards n Haime are, according to specimens bearing those names in h Museum of Natural History at Turin, referable to *Orbicella annul is*

The type of Duncan's *Cyphastraea costata* from Barbuda is re served in the Geological Society of London, and I studied it th re The specimen shows no noteworthy variation from the usual *Orbi la annularis,* except that its calices are from 3 to 4 mm. in diam r, usually 3.5 mm. Another specimen, from Santo Domingo, lab el *Cyphastraea costata* is a *Solenastrea.* The specimens determine by Gregory as *C. costata* were studied in the British Museun of Nat al History; they are *O. annularis.*

Astraea barbadensis Duncan is a specimen of *O. annularis* from h Pleistocene reefs of Barbados.

[1] Illustrations of this specimen have been published by me in U. S. Geol. Surv. Prof. Pap. 98-T, 9 figs. 3, 3*a*, 1917.

Gregory refers *Heliastraea altissima* Duncan to the synonymy of s species, but I doubt the correctness of his conclusion and am ating it as valid.

Geologic distribution.—Pleistocene and Recent, throughout the vated reef areas of the West Indies, eastern Central America, and rida.

Duncan [1] has listed *Astraea barbadensis*, one of the synonyms of *annularis*, from the "marl formation" of Antigua, remarking that it greatly altered by fossilization; the calicular surface is subplane, the calices are seen as prominent columnar casts." Should ncan's identification be correct, the geologic range of *O. annularis* ends from Oligocene time to the present. Mr. R. T. Hill obtained Antigua a silicified specimen that looks like *O. annularis*, but I am sure that it is that species.

osta Rica, station 4269, Port Limon, collected by Doctor Wailes eds referred to the Pliocene. There are three dissociated coral- which have the general characters of *Orbicella annularis*, but are absolutely typical, for the primary septa are appreciably but not ingly thicker than the secondaries. They are, therefore, somewhat rmediate between typical examples of the species and *Orbicella bata* (Duncan).

2. ORBICELLA LIMBATA (Duncan).

Plate 85, figs. 1, 1*a*, 2, 2*a*, 2*b*, 3, 4, 4*a*.

1863. *Phyllocoenia sculpta* var. *tegula* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 432.

1863. *Phyllocoenia limbata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 433.

1864. *Plesiastraea ramea* DUNCAN, Geol. Soc. London Quart. Journ., vol. 20, p. 39, pl. 5, figs. 1*a*, 1*b*.

1866. *Phyllocoenia limbata* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 76 (of reprint).

1866. *Plesiastraea ramea* DUCHASSAING and MICHELOTTI, Sup. Mém. Corall. Antilles, p. 87 (of reprint).

1868. *Phyllocoenia limbata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 23.

1868. *Plesiastraea ramea* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 25.

1870. *Phyllocoenia limbata* DUCHASSAING, Rev. Zooph. et Spong. Antilles, p. 28.

1870. *Plesiastraea ramea* DUCHASSAING, Rev. Zooph. et. Spong. Antilles, p. 30.

Original description of *Phyllocoenia limbata:*[1]

Callum in the shape of *Stylina limbata* Edwards and Haime. Stem large id cylindrical. Corallites numerous, irregularly placed. Calices separated by ju coenenchyma, circular and but slightly elevated. Costae covering much rf e. Slightly dentate where they approach, and turning aside from those of other di s; they are not continuous, not very prominent, and slightly granular. Septa pt ojecting far inwards, laminae granular; their upper margin is neither incised nor en te; in six systems of generally three cycles, though occasionally of four. Pri-

[1] Geol. Soc. London Quart. Journ., vol. 19, 1863, p. 433.

mary septa largest. Columella rudimentary. Endotheca abundant. Diameter calice, with costae, one-fifth inch [5 mm.].

The deficient columella is the only point in which this species differs from *M pora limbata* Goldfuss, which has been determined by Milne Edwards to be a *Styl*

From the yellow shale of San Domingo. Coll. Geol. Soc.

Original description of *Plesiastraea ramea:*[1]

Corallum in gibbous masses or more or less cylindrical processes with irre swellings. Calices distant, very slightly exsert, circular, and unequal in Septa thick at the wall, thin internally, unequal in size, according to orders: finely dentate above, but sparely granular laterally. In six systems of t cycles, with occasionally an additional order in one-half of a system. Pali small. Columella lax, papillated, and small. Fossa moderately deep. Costae developed, subequal, and marked by three or four dentate projections: they are dently covered with a fine epitheca, which is not granular; where the epitheca is the costae are seen to be smaller, the tertiary being much smaller than the other project, however. Exotheca moderately developed and often becoming indur Endothecal dissepiments fragile, but horizontal and frequent. Height, some in diameter of branches 1 inch, more or less; diameter of corallites four-thirtieths [3.3 mm.]; distance between corallites about one-tenth inch [2.5 mm.].

From the silt of the Sandstone plain, San Domingo. Coll. Geol. Soc.

I examined Duncan's types of *Phyllocoenia limbata* and *Plesiast ramea* in the Geological Society of London and made a note that latter, except that its septa are broken down and the calices ha hollowed-out appearance, is the same as the former.

In my Some fossil Corals from the elevated Reefs of Cura Arube, and Bonaire, and my Stony Corals of the Porto R waters, I placed in the synonymy of *Orbicella acropora* (*annularis*), the three names of Duncan, cited above, considering specimens to which they were applied as growth forms of that spe More detailed studies, subsequently made, have led me to bel that I was mistaken in that course. This coral is very similar t *annularis*. However, there appear to be two constant differenc namely, the primary septa within the calices are uniformly thi and usually longer than the secondaries (this lesser developme the secondaries is not occasional as in *O. annularis* but constant) small, but distinctly developed, pali occur before the primary secondary septa.

I have for study one specimen from Duncan's original mat labeled *Plesiastraea ramea* Duncan, No. 155273, U.S.N.M., ki sent to the United States National Museum by the authorities o Geological Society of London (see pl. 85, figs. 1, 1*a*); 10 speci belonging to the Museum of Comparative Zoology, 4 speci collected by Miss C. J. Maury in Santo Domingo, and mat obtained by myself near Santiago, Cuba. The first specimen i in very good condition for study, and does not fit Duncan's des tion well. The Museum of Comparative Zoology specimens, how

[1] Geol. Soc. London. Quart. Jour., vol. 19, 1863, p. 421.

exactly, omitting the remarks about the costae being covered by itheca. The figures presented on plate 85, figs. 2, 2*a*, 2*b*, and 3, e based on these specimens.

Phyllocoenia sculpta var. *tegula* Duncan.[1] As I do not find Dunn's description of this coral satisfactory, and as the authorities of e Geological Society of London have kindly sent one of the original ecimens to the United States National Museum (No. 155274), e pl. 85, figs. 4, 4*a*), I submit the following description:

Corallum, a rather thick folium; the specimen here described is unfortunately broken on all its edges, its original dimensions are therefore unknown. Its present length is 62 mm.; width 40 mm.; greatest thickness, 15.5 mm.; thickness near outer edge 5.5 mm. Base incrusted with a coarsely wrinkled epitheca.

The calicular margins are on the same level as the flat exothecal surfaces, or are very slightly raised. In form the calices are circular somewhat deformed. Diameter from about 2 mm., to 2.5 by 3.5 mm.; distance apart, from 1 to 3 mm. Intercorallite areas with costae, beaded on the edges, equal or alternating in size, corresponding to all septa, those of one calice meeting those of the adjoining calices.

Septa usually in three complete cycles, primaries and secondaries larger, and usually thicker, than the tertiaries, primaries average larger than the secondaries. All the primaries and most of the secondaries reach the columella.

Columella trabecular.

Locality and geologic occurrence.—Nivajè shale, Santo Domingo, t. Duncan.

Miss Maury obtained specimens in Santo Domingo as follows: Rio Cana, zone H, associated with *Placocyathus*, new species, *Stylophora granulata* Duncan, *Antillia bilobata* Duncan, *Orbicella baindgensis* Vaughan?, *Solenastrea bournoni* M. Edwards and Haime, *Syzygophyllia gregorii* (Vaughan), and *Siderastrea siderea* (Ellis and Solander). Rio Gurabo, zone D, associated with *Stylophora affinis* Duncan, *Madracis decactis* (Lyman), *Pocillopora crassoramosa* Duncan, *Stephanocoenia intersepta* (Esper), *Orbicella cavernosa* var. *cylindrica* (Duncan), *Syzygophyllia dentata* (Duncan); zone not stated, associated with *Pocillopora crassoramosa*, *Thysanus grandis* (Duncan), and *Syzygophyllia dentata* (Duncan).

collected in 1901 a fine specimen of this species east of La Cruz, at the crossing of the highway from Santiago to the Morro over the railroad, near Santiago, Cuba. Other corals collected there, including *Stylophora* species (probably *S. affinis* Duncan), *Solenastrea bournoni* M. Edwards and Haime, a species of *Thysanus* (aff. *T. excentricus* Duncan), *Siderastrea siderea* (Ellis and Solander), and *Goniopora*

[1] Geol. Soc. London Quart. Journ., vol. 19, p. 432, 1863.

jacobiana Vaughan, indicate similarity in horizon with zone D of th Rio Gurabo section.

3. ORBICELLA IMPERATORIS, new species.

Plate 86, figs. 2, 3, 4, 5.

Corallum forming rounded masses 16 cm. or more in diameter.

Calices in the type-specimen are not much elevated but have a di tinct, somewhat raised wall; in other specimens the corallites m project as much as 2.5 to 3 mm. Calicular diameter, 3.5 to 5 mm distance between calices, from 2 to 3.5 mm. Corallites joined l prominent, rather thin, distant costae, which correspond either all cycles of septa or to the primaries and secondaries.

Septa, typically in three complete cycles; the 6 primaries pron nent, thicker than the members of the higher cycles, and exte to the columella; the secondaries usually do not reach the columel only about half as long as the primaries; tertiaries shorter and thi ner than the secondaries. The septa are usually distant in the wa The third cycle of septa is incomplete in some calices; while in lar calices a few secondaries may reach or almost reach the columella.

Columella formed by the fusion of the inner edges of the prima septa.

Endotheca well developed as dissepiments. Exotheca well dev oped between the strong costae, about 3 dissepiments within 1.5 m

Localities and geologic occurrence.—Canal Zone, Panama, in t Emperador limestone, at stations 6015 and 6016, quarries in Empi and 6017, one mile from Empire toward Las Cascadas, collected T. W. Vaughan and D. F. MacDonald; station 6256, in the Emperad limestone, 1½ miles south of Miraflores, collected by D. F. MacDona

Cuba, station 3450, 4 miles north of the City of Pinar Rio, and station 3451, one-half mile west of Cienaga railroad stati near Habana, collected by T. W. Vaughan; station 3566, Beju collected by Arthur C. Spencer; station 7544, Rio Yateras, n Guantanamo, collected by O. E. Meinzer. N. H. Darton, collec at station 7664, on the north slope of La Piedra, northeast of Jamai which is northeast of Guantanamo, a specimen of *Orbicella* apparen referable to this species. The calices are rather large, 7 mm. diameter, and nearly all of the secondary septa reach the columel It seems very near *O. antillarum*. The specimens from Ciéna Cuba (pl. 86, fig. 5), is illustrated as well as the cotypes from Pana

Anguilla, stations 6893 and 6967, Crocus Bay, collected T. W. Vaughan.

Cotypes.—No. 324884, 324902, 324903, U. S. N. M.

Paratype.—No. 324878, U. S. N. M.

This species is distinguished by the small size of its calices, prominent costae, its 6 long septa, with intermediate septa sho according to cycle.

4. ORBICELLA ANTILLARUM (Duncan).

1863. *Astraea antillarum* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 443.

1866. *Astraea antillarum* DUCHASSAING and MICHELOTTI, Sup. Corall. Antilles, p. 86 (of reprint).

1867. *Heliastraea antillarum* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

1870. *Heliastraea antillarum* DUCHASSAING, Rev. Zooph. Antilles, p. 30.

This coral was doubtfully referred by me [1] to the synonymy of *Orbicella cavernosa;* but, as there is doubt, it is here accorded specific treatment.

Original description.—"A specimen in the form of a rolled flint, found with silicified wood, has the corallum large, tall, probably resembling in shape that of the San Domingan *A. exothecata*. Corallites close, unequal in size, but quite distinct; the transverse section shows them to be circular in outline. Septa in six systems of three cycles. The primary and secondary septa are nearly equal, and reach to the columella; the tertiary are small and straight; all are slender, wide apart, and very distinct. Costae tolerably developed, subequal. Walls moderately developed, by no means strong. Columella small, and occupying a small space. Endotheca greatly developed, vesicular, and forming cells between the septa. Exotheca well developed; large cells broad, others squarer, with shelving dissepiments. Diameter of the corallites three-tenths inch [7.5 mm.]. The interspaces are filled with opalescent or porcellanous silica; sclerenchyma often destroyed. Coll.-Geol. Soc."

Locality.—Montserrat.

Duncan [2] lists a coral as *Astraea antillarum* variety, and makes the following note: "With more distant calices than the type, produced costae, and a less perfect development of the third septal cycle. The exact locality is not known, but the coral, from its mineralogical characters, appears to have been obtained from Antigua. Brit. Mus."

Regarding the apparent absence of a fourth cycle of septa, it will be noted that as they are often very small and may be broken away, something especially likely to occur in worn specimens such as corals usually are, they may have been present, but were subsequently destroyed. The size of the calices, 7.5 mm. in diameter, suggests the presence of quaternary septa. Additional material from Montserrat is needed to solve the question.

5. ORBICELLA ALTISSIMA (Duncan).

1867. *Heliastraea altissima* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, pp. 12, 24, pl. 2, fig. 3.

Original description.—"The corallum is very massive and tall, and the upper surface is subplane and wider than the base. The calices

[1] Geologisch. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, pt. 1, p. 28, 1901.

[2] Geol. Soc. London Quart. Journ., vol. 20, p. 36, pl. 4, fig. 2.

are barely above the common surface, they are circular, but occ sionally deformed, and they are slightly unequal in size. The calicul fossa is shallow, and the calicular margins are broader than tl septa. The columella is small, distinct, lax, and parietal. T costae are well marked, unequal, and rarely touch, and they a thicker than the septa. The costae of the highest order are w developed, and contrast with their rudimentary septa. The sep are delicate, they are thinner midway than elsewhere, and the which reach the columella have a paliform tooth; they are not exse and are only slightly dentate. The septa are very irregular in th arrangement. There are six systems, and in most of them the are three cycles with or without a part of a fourth in one-half of t system, so that there are constantly six septa in a system inste of eight. The endotheca is well developed; and the dissepimer are close, stout, and nearly horizontally parallel. The exotheca abundant, forming small cells with arched outlines. Height corallum 6–8 inches. Diameter of calices two-tenths inch [=5 mm.

Locality.—St. Croix, Trinidad.

Gregory [1] places Duncan's *Heliastraea altissima* in the synonyı of *Orbicella acropora* (Linnaeus), without giving his reason. He m be right, but the calices are large for *O. acropora* (here called *annularis*), and judging from the presence of quaternary septa it almost certainly distinct. According to Duncan's figure every otl septum reaches the columella, a septal arrangement which is one the characteristics of *O. annularis*. I did not see the type in Lond and think that until it is restudied or additional material has b collected at the type locality, it will not be possible to reach a posit decision as to the validity of the species.

6. ORBICELLA CAVERNOSA (Linnaeus).

Plate 87, figs. 1, 1*a*, 1*b*, 1*c*; plate 88, figs. 1, 2, 3, 3*a*, 3*b*.

1766. *Madrepora cavernosa* LINNAEUS, Syst. Nat., ed. 12, vol. 1, p. 1276.
1901. *Orbicella cavernosa* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., 2, vol. 2, p. 27 (Synonymy with exceptions noted below).
1902. *Orbicella cavernosa* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 1 102.
1915. *Orbicella cavernosa* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p.
1916. *Orbicella cavernosa* VAUGHAN, Carnegie Inst. Washington Year Book No p. 227.

In my first paper referred to in the synonymy I placed *Astraea dothecata*, *Astraea cylindrica*, and *Astraea brevis* of Duncan in synonymy of this species. *A. endothecata* and *A. cylindrica* seem to me to deserve varietal recognition and *A. brevis* should treated as a valid species until additional information concernin is available. Duncan's *Astraea antiguensis*, which I doubtf

[1] Geol. Soc. London Quart. Journ., vol. 51, p. 272, 1895.

ced in the synonymy of *O. cavernosa*, has the general appearance *Orbicella*, but it is a fungid coral and is referred to the genus *athomorpha*. *Astraea antillarum*, given by me as doubtfully a nonym of *O. cavernosa*, should for the present at least be treated a valid species.

As so many of the species related to *O. cavernosa* must be con-ered in this paper, it is desirable to describe all those members of group found in the American Tertiary formations and now ing in the western Atlantic Ocean. The systematic rank of the ms described on the following pages is open to debate, and I wish e to express my recognition of other methods of treatment. As forms, whether they be designated "species," "subspecies," ariations," or merely "variants," exist, and as they have geographic l geologic significance, they should be discriminated and char-erized. In comparison with these desiderata nomenclatorial siderations are of secondary importance.

Orbicella cavernosa is so variable that great difficulty has been erienced in constructing an intelligible description. A very eresting specimen, obtained by Prof. J. E. Duerden in Jamaica presented by him to the United States National Museum, will be described in detail, as it shows within itself a wide range of iation and indicates the lines of variation of other specimens e constant in their character (see pl. 87, figs. 1, 1*a*, 1*b*, 1*c*).

The corallum is oblong; upper surface convex but not uniformly ned or domed; base epithecate. Length, 25 cm.; breadth, 20 ; thickness, 11.3 cm.

The specimen has two different kinds of calices. Those of one al are rather distant, protuberant, and have subequal, not very thick, dentate costae (pl. 87, fig. 1). The transverse outline is ular or broadly elliptical, diameter between thecal summits m.; one of the elliptical calices has a greater diameter of 11 mm., er about 9 mm. The costae are about 1 mm. tall. The distance t, measured between the outer costal edges, is from almost iguous to 6 mm. The free limb of the corallite is subcylindrical projects between 6 and 7 mm. The calices, as is shown by le 87, figures 1, 1*a*, are not uniformly distributed, and vary in form, and prominence.

a fully developed calice there are 48 septa, every other one nding to and fusing to the columella. All the septa, particularly principals, are rather thick. The margins are dentate, within alicular cavity, they fall abruptly to the bottoms of the calices, h are 3 to 4 mm. deep, and there the principals extend to the nella. There are septal teeth around the periphery of the nella but they are not in the form of well-developed pali or orm lobes.

The columella is large, trabecular, with a papillate upper surfa diameter, as much as 4 mm. The columellar elements are rat often twisted and present a whorled appearance.

Endothecal dissepiments rather delicate; exotheca, coarse very vesicular.

The calices of the other kind (pl. 87, fig. 1*a*) in their typical de opment are smaller than those above described, their edges only slightly elevated, and the septa and costae are decidedly t and exsert. Diameter of the calices from 5 to 8 mm.; septal mar 2 mm. tall.

The differences between these two kinds of calices are so gr that it seems scarcely possible that they could belong to the s species; however, they occur on the same corallum where per intergradation can be traced.

Pourtalès, as far back as 1871,[1] published the following import notes on this species:

> There is considerable variation among the specimens from Florida in the Museu Comparative Zoology, enough apparently to warrant placing them among the t species mentioned in the synonymy; but by carefully examining the different of each specimen, passages from one to the other can be found. Thus young po doms, expanding rapidly laterally and with rather distant polyps, appear at fi differ considerably from strongly convex ones with crowded calices; the costa larger, flatter, and less sharply denticulate, and the border of the calicles less elev
>
> The size of the calicles, relied on to divide the genus into groups by Milne Edw and Haime, is a very uncertain character; one specimen has in one part the cal varying from 3.5 to 4 mm., in another from 7 to 8 mm. The same specimen h some parts the contiguous walls united solidly, with very few or no exothecal cel others separated by an abundant cellular exotheca. In worn specimens the last disappears first, for that reason probably *Orbicella* (*Madrepora*) *radiata* Ellis has characterized by the Milne Edwards and Haime as having but three cycles.

Verrill gives the following description:[2]

> Much of the confusion in regard to the name of this species is due to the fact tl was generally described and figured from badly beach-worn specimens by the e writers. Such specimens have the septa and calicles worn away and the har otheca thus becomes prominent around the excavate calicles, so as to greatly ch the appearance of the coral. Another cause is the rather wide variations in th of the calicles.
>
> The normal or average specimens have the calicles about 6 to 8 mm. in dian but occasionally a specimen occurs in which part or all of them may be 9–10 m rarely, even 11 mm. in diameter. Sometimes, on crowded parts of large speci the diameter may be only 4 to 5 mm. The degree of elevation of the calicles i more or less variable on a single specimen.
>
> The calicles may be pretty close together, where crowded, but in other cases are separated by spaces of 4 to 6 mm. or more. The costae are usually well deve as denticulated, rounded, radial ribs, usually 48 in number.
>
> The septa are generally about 48, arranged in four regular cycles, but seve those of the last cycle are often rudimentary or lacking, reducing the number to 4

[1] Mus. Comp. Zool. Ill. Cat., No. 4, p. 76.

[2] Trans. Conn. Acad. Arts and Sci., vol. 11, pp. 102, 103, 1902.

ey differ in breadth and thickness according to the cycles; those of the last cycle very thin and often bend toward and join those of the third cycle. The principal ta are exsert, denticulated, and thickened at the wall. The columella is usually l developed and broad. The paliform teeth are distinct, but not very prominent. ometimes forms hemispherical masses 4 to 5 feet or more in diameter.

his species appears to be rare at the Bermudas, and probably occurs only on the ermost reefs. The only specimen seen by me from there was from near the North ks. (Centennial collection.) It is a hemisphere about 11 inches in diameter, of typical form. It is common on the Florida reefs and throughout the West Indies. ia, Brazil; (Yale Mus.);=var. *hirta*, nov., with elevated corallites; roughly serrate n costae and septa; calicles deep, 5–6 mm. broad; septa narrow, perpendicular nin, usually 40–44.

The description of the Jamaican specimen, when taken in connection with the notes by Pourtalès and Verrill, gives a good idea of the ent of the variation of the species except in one particular, that of septal arrangement. The normal, fully developed calices have four aplete cycles of septa; however, sometimes the fourth cycle may be complete while at others there may be a few quinaries. In recent specimens the tertiaries usually, but not invariably, end to the columella.

The characters common to all of the specimens may be briefly amarized as follows:

Corallum massive, base epithecate, upper surface flat, irregularly vex, or domed. Calices more or less elevated, diameter from 5 to mm., externally costate, costae normally subequal. Septa norlly in four complete cycles, the members of the first three cycles end to the columella, but the fourth may not be complete, and metimes there may be a few quinaries. Columellar trabecular, l developed, large, with a papillary upper surface.

Remarks on the synonomy of O. cavernosa.—The names *O. radiata* llis and Solander), *O. argus* (Lamarck), *O. conferta* (Milne Edwards Haime), and *O. cavernosa* var. *hirta* Verrill, are definitely placed the synonymy of *O. cavernosa*, and it is thought probable that *braziliana* Verrill, should be referred to it. These names will be ussed seriatim.

Gregory applies *O. radiata* to this species, as he considers the Linan definition of *Madrepora cavernosa* insufficient, an opinion with ch I do not agree. All the Linnaean descriptions are unsatisfactory, in this instance Linnaeus refers to the figures of Seba, he places the *Madrepora astroites* of Pallas in its synonymy, and he states "Habitat n). Americano." Taking all things together, the original diagnosis the references seem to me sufficient for purposes of identification—in fact, the brief Latin description is not bad. *O. radiata* was posed to differ from *O. cavernosa* by possessing only three cycles septa. Pourtalès states, in the quotation already made from him, "In worn specimens the last cycle disappears first; for that on probably *Orbicella* (*Madrepora*) *radiata* Ellis and Solander has

been characterized by Milne Edwards and Haime as having
three cycles."

Lamarck's *Astrea argus* is a new name for the *Madrepora cavern*
Esper. The reason for his giving it is not evident.

The specimen identified by Ehrenberg as *Explanaria argus*, wh
is the type of Milne Edwards and Haime *Astrea conferta*, is in
Berlin Museum für Naturkunde, and the following notes are ba
upon it:

The specimen is much worn and is apparently somewhat fossiliz
The calices are not regularly rounded, but frequently are of irregu
polygonal outline. The greater diameter of an average calic
8.5 mm.; lesser 7 mm. Thickness of wall between the calices is
mm. In one calice there were 21 large and 21 smaller septa; th
may be four complete cycles in some calices. The columella is v
large and vesicular and occupies the greater part of the coral
cavity. Dissepiments abundant, about 13 to 5 mm.; they sl
downward and inward. From reading the Pourtalès descript
quoted above, it will be evident that this is only a variety of
cavernosa with crowded calices. The *Explanaria radiata* of Ehrenb
is the ordinary *Heliastraea cavernosa* as figured by Milne Edwa
and Haime, except that the fourth cycle of septa may not always
complete.

Orbicella cavernosa var. *compacta* Vaughan (pl. 88, figs. 3, 3*a*,
has solid exotheca, low mammillate corallites, and equal cos
Recent on the Brazilian coast; lat. 12° 48′ S., long. 38° W.;
fathoms.

Localities and geologic occurrence.—On the living and Pleistoc
reefs of Florida, the West Indies, and the Caribbean side of Cen
America. There are beach worn or Pleistocene specimens from
Isthmus of Darien in the United States National Museum, collec
by Dr. Van Patton.

6a. ORBICELLA CAVERNOSA var. ENDOTHECATA (Duncan).

Plate 89, figs. 1, 1*a*.

1863. *Astraea endothecata* DUNCAN, Geol. Soc. Lond. Quart. Journ., vol.
p. 434, pl. 15, figs. 7*a*, 7*b*.

1868. *Heliastraea endothecata* DUNCAN, Geol. Soc. London Quart. Journ., vol
p. 24.

The corallite walls are thick; costae strongly alternating in s
the last cycle are small and thin, and there appear to be no se
corresponding to them; occasionally there is a rudimentary sept
of the fourth cycle. The last cycle of septa may have been bro
off; or the wall, because of subsequent thickening, may have inclu
their inner ends; all other septa, with rare exceptions, extend to
large, well developed columella. Diameter of corallites from 8

m. Type in the Geological Society of London; duplicate in the ed States National Museum (No. 155276). The preceding re- s are based on the latter.

calities and geologic occurrence.—Type said to come from the jè shale of Santo Domingo.

sta Rica, station 4269, Port Limon; collected by Doctor Wailes bed of reputed Pliocene age. The size of the calices, and the e, wall, and columella of the Port Limon specimen are as in var. *hecata;* but usually every other septum meets the columella; a of small septa between the larger is clearly present. As it is able that the last cycle of septa has been destroyed in the type of *endothecata*, the presence of small septa between the larger would ndicate specific difference. The strongly developed costae with l ones between them are the same in both the type and the Port on specimens.

e stratigraphic range of this variety, therefore, is from the jè shale (lower Miocene) to probably Pliocene.

6b. ORBICELLA CAVERNOSA var. CYLINDRICA (Duncan).

Plate 89, fig. 2.

63. *Astraea cylindrica* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 434, pl. 15, fig. 8.

68. *Heliastraea cylindrica* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

is variety closely resembles var. *endothecata*. It has smaller lites, 5 to 6 mm. in diameter; fewer septa, 12 to 16 principal , with from 1 to 3 smaller intermediate septa. Between each of larger septa on the mural summits around the calices is an mediate rudimentary septum; the total number of septa is ct 38. The costae corresponding to the principal septa are ingly prominent, while those corresponding to the rudimentary . are very small or even obsolete. The calice is rather deep, ct 2.5 mm.

is coral may be only a growth facies of *O. endothecata*.

calities and geologic occurrence.—Duncan type, in the Geological ty of London, comes from "the tufaceous limestone" of Santo ingo; duplicate specimen No. 155277, U.S.N.M. Miss C. J. y has recently collected the variety in Santo Domingo as fol- w:

o Gurabo, zone D, associated with *Stylophora affinis* Duncan, *aracis decactis* (Lyman), *Pocillopora crassoramosa* Duncan, *anocoenia intersepta* (Esper), *Orbicella limbata* (Duncan), *Orbi- cavernosa* (Linnaeus) var., *Syzygophyllia dentata* (Duncan), single specimen collected is essentially typical, in fact it is a r specimen than Duncan's type. Cercado de Mao, without

more specific information. The latter specimen has corallites v somewhat larger diameter, as much as 7.5, than those of typ specimens, diameter 4.5 to 5 mm., in that respect more clo resembling var. *endothecata*, but there are no or only a few s costae between the large ones, and the septal characters are n similar to those of var. *cylindrica*.

Costa Rica "Colline en démolition", Port Limon, No. 669, o lection of H. Pittier. The specimens from Port Limon consis two isolated corallites, which so closely resemble those of the t of var. *cylindrica* as not to need comment. Except in size, they very similar to var. *endothecata*.

7. ORBICELLA APERTA (Verrill).

Plate 89, fig. 3.

1868. *Heliastraea aperta* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 1, p 5
1902. *Orbicella aperta* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 2, p 0 pl. 33, figs. 1, 1*a*.

This species is especially characterized by having the prin septa, that is, those of the first, second, and third cycles, all of w ordinarily reach the columella, taller and thinner than is usu *O. cavernosa*. At one time I was inclined to consider it only a va of *Orbicella cavernosa*, but comparisons of large suites of *O. caver* from Florida and the West Indies with a good suite of *O. a* from Brazil shows persistently recognizable differences.

Localities.—Abrolhos reefs, Bay of Bahia, and Island of Itapa Brazil.

8. ORBICELLA BAINBRIDGENSIS, new species.

Plate 90, figs. 1, 1*a*, 1*b*, 1*c*.

In growth form, general aspect of the corallum, and size of c similar to *Orbicella cavernosa*.

Calices 6 to 7 mm. in diameter; walls slope from calicular ma to bottom of intercorallite areas; protuberant about 2 mm.; dis apart from 1.5 to 3.5 mm.

Costae subequal, relatively thick, rather low, beaded on th edges, correspond to all septa, meet in the intercorallite depres

Septa in nearly four complete cycles, 10 to 12 septa, i. e th primaries and most or all of the secondaries are thicker tha other septa, these and in some calices a variable number of ter extend to the columella. Usually the tertiary septa do not columella, and the quaternaries are still shorter. The sept distinctly of three sizes, even where the tertiaries reach the colu they are thinner than the members of the lower cycles. S margins dentate; distinct, rather wide, erect paliform lobes on the inner ends of the primaries and secondaries and in on the tertiaries; on some septa instead of paliform lobes ther

veral teeth with rounded upper ends. The youngest septa are rgely composed of ascending spines which are not completely fused. Columella relatively large, composed of septal trabeculae, upper rface coarsely papillate.

Endothecal dissepiments highly developed, forming curved vesicles. kotheca composed of successive, superposed but separated plat-ms extending between corallites (see pl. 90, fig. 1*c*).

Localities and geologic occurrence.—Georgia, stations 3881, Blue ring, 4 miles below Bainbridge, and station 3883, Hales Landing, miles below Bainbridge, Flint River, Decatur County, collected by W. Vaughan; in the basal part of the Chattahoochee formation, just ove the contact with the Ocala limestone. In the base of one ecimen from station 3383 there is a cast of the surface of *Cerithium ughani* Dall, and there are several specimens of orbitoidal foram-fera, one of which is clearly a species of *Lepidocyclina*. Stations 35, Withlacoochee River, a few hundred yards below the Val-sta Southern Railway bridge, and 6084, about 3 miles below the ne bridge, Lowndes County, Georgia, collected by L. W. Stephen-n.

Type.—No. 324881, U.S.N.M.

Santo Domingan specimens, representing a very closely related if identical species, were obtained by Miss C. J. Maury, on Rio a, in what she refers to as zone H, in association with a fauna resenting the Bowden horizon, namely, *Placocyathus* new species, *lophora granulata* Duncan, *Antillia bilobata* Duncan, *Orbicella lim-i* (Duncan), *Solenastrea bournoni* M. Edwards and Haime, *Syzy-hyllia gregorii* (Vaughan), and *Siderastrea siderea* (Ellis and ander).

9. ORBICELLA COSTATA (Duncan).

Plate 91, figs. 1, 1*a*, 2, 3, 3*a*; plate 92, figs. 1, 2, 3; plate 93, figs. 1, 1*a*.

1863. *Astraea costata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 422, pl. 13, fig. 9.

1867. *Heliastraea costata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

riginal description.—"The specimens of this species which I have mined present polished longitudinal and transverse sections of allites, but I have seen no calices. Corallites long, parallel, some-es deformed, generally circular in transverse outline, not crowded, close, varying in size. Intercorallite spaces very distinct. Walls , not thicker than the delicate septa. Costae large alternately, n sizes equally produced; wedge-shaped at the wall, pointed, and n bent at the free end. Septa all delicate and linear near the mella and in the middle; at the wall their base is narrower than of the costae. They are arranged in six systems, the cycles g very irregular. In three systems there are three cycles, and he rest an incomplete fourth; rarely there are two systems with

four complete cycles; the fourth and fifth orders often curve tow the third order. Lamellae rather cribriform, joining the colum by oblique processes. Columella lax, small, and formed by diss ments from the septa and a central spongy mass. Endotheca v abundant, vesicular, and horizontal, with four or five dissepim in one-tenth inch [2.5 mm.]. Exotheca abundant, nearly equa the endotheca. Reproduction by extra-calicular budding. Di eter of the corallites from three-tenths to seven-twentieths inch to 8.25 mm.].

"This species is closely allied to the astraeans with great e thecal development, and especially to *Astraea vesiculosa* Edw and Haime, from Dax, as well as to *A. antillarum* nob., and *endothecata* nob."

Locality.—"The Marl of Antigua."

Illustrations based on one of Duncan's original specimens, but o the type, are given on plate 91, figures 1, 1*a*.

This species is represented in the Antigua formation of Anti the Pepino formation of Porto Rico, the Culebra formation of Canal Zone, and in the marls and limestone of Anguilla. The p cipal variation consists in the size of the calices. The minimum of the calices in the Antiguan specimens (pl. 91, figs. 2, 3, 3 about 7 mm., which is about the average for the Porto Rican s mens (pl. 92, fig. 1), and the calices of the specimens from the Zone (pl. 92, fig. 2) average slightly smaller than those from Rico, but the two sets of specimens differ very little. In Ang (pl. 92, fig. 3; pl. 93, figs. 1, 1*a*) the large and small calicled form found in association.

The amount of the protuberance of the corallites varies gre but protuberant and low corallites are found on the same coral Usually where the corallites are low the alternation in size o costae is not so pronounced as where the corallites are exsert; some protuberant corallites of the specimen represented by plat figure 3, have equal costae on at least one side.

There are pali before all except the last cycle of septa: the moderately wide, erect, rounded above, form two crowns.

Localities and geologic occurrence.—Antigua, in the Antigua fo tion, at station 6881, Willoughby Bay, collected by T. W. Vau

Porto Rico, in the Pepino formation, station 3191, 4 miles w Lares, collected by R. T. Hill.

Canal Zone, in the Culebra formation, at station 6020*c* Las Cas collected by Vaughan and MacDonald.

Anguilla, stations 6893, 6894, 6966, in the lower and the m beds on the south and west sides of Crocus Bay; 6969*a*, botto at Road Bay.

This species in its general aspect resembles *Cyathomorpha belli* aughan (see p. 459), but has thinner septa and costae and deeper alices. The lower surface is more or less invested with epitheca, nd no synapticulae could be found.

10. ORBICELLA CANALIS, new species.

Plate 94, figs. 1, 1*a*, 2, 2*a*, 3, 3*a*; plate 97, figs. 4, 4*a*.

This species can best be characterized in terms of comparison with *costata*. The growth forms and the general facies of both are nilar, except that the maximum size of the calices in *O. canalis* nearly the minimum size in *O. costata;* range in calicular diameter *O. canalis* from 5 to 9 mm., average about 6 or 6.5 mm.

The costae in *O. canalis* are alternately large and small or sub-ual around the calicular edge below which they may be subequal, ternately large and small, or the last cycle may disappear.

Septa in 4 or nearly 4 cycles: primaries notably larger than the condaries except in occasional unusually large calices, and each lars a strong tooth on its inner end: secondaries thinner than the imaries, also with a tooth on the inner end, these and the primaries ach the columella; tertiaries shorter, but with a paliform thickening a tooth on the inner end; quaternaries decidedly small. The pta usually are lanceolately thickened in the wall, in this character embling typical *O. costata.*

The columella is formed by the fusion of the inner ends of the pta and is less developed than in *O. costata.*

Endothecal dissepiments well developed, thin, from 0.5 to 1.5 mm. art. Exotheca consists of thick-walled blister-like, small vesicles, out 0.5 mm. high, and more or less wavy platforms which extend tween the corallites.

Localities and geologic occurrence.—Canal Zone stations 6015 and 6 6, quarries in the Emperador limestone, Empire, collected by W. Vaughan and D. F. MacDonald, also collected in Empire by lph Arnold.

nguilla, stations 6894, lower bed; 6966, middle bed, between 5 and 75 feet above the base of the section; and 6967, upper bed, st side of Crocus Bay, collected by T. W. Vaughan.

Type.—No. 324862, U.S.N.M. (pl. 94, figs. 1, 1*a*).

Paratypes.—No. 324861, U.S.N.M. (pl. 94, figs. 2, 2*a;* pl. 97, figs. 4, 4*a*. The specimen represented by plate 94, fig. 3, 3*a* No. 324859, U.S.N.M. is a varietal form that appears referable to *O. canalis;* it is fr n Anguilla.

rbicella canalis is so nearly related to a number of Antillean upper Oligocene species, that I have hesitated to apply a distinctive name, bu as the large suite of specimens before me, 30 of those from Empi , Canal Zone, have been selected as the reserve series of the U ted States National Museum, shows characters by which they

can be discriminated, it seems logical to recognize them as a spec
Stylangia panamensis has a general resemblance to those specim
of *O. canalis* in which the corallites are small and the costae
very prominent; but the corallites of *O. canalis* are larger, and t
have not the lamellate columella of *S. panamensis*. Small-calic
specimens with prominent, strongly alternating costae resemble
imperatoris, and differ from the latter by their somewhat lar
calices and more numerous septa. The calices of *O. costata* a
larger, the primary and secondary septa are subequal, and the
umella is more developed. In both *O. intermedia* and *O. cos*
the secondary septa are more developed. Larger suites of sp
mens than are at present available may lead to the reduction of s
of these names to subspecific or varietal rank.

11. ORBICELLA TAMPÄENSIS, new species.

Plate 95, figs. 1, 2, 2*a*, 3, 3*a*.

1915. *Orbicella cavernosa* var. *tampäensis* VAUGHAN, *nomen nudum*, U. S.
Mus. Bull. 90, p. 18.

The corallum forms head-shaped masses up to the size of a m
fist.

Calices deep, decidedly elevated, up to 4 or 4.5 mm.; diam
from 6 to 10 mm. Costae prominent, distant; there are no or
rudimentary costae corresponding to the last cycle of septa.

Septa, distant, in four cycles, the fourth usually more or less
complete. The primaries and some or all of the secondaries, o
sionally a tertiary, reach the columella. Usually there are thre
four different sizes. On the inner ends of the primaries are palif
teeth, below which the margins fall steeply to the bottom of the fo
Margins of the primaries exert as much as 1.5 mm.; those of se
daries almost as prominent; those of the tertiaries less promin
those of the quaternaries inconspicuous. Septa thickened in the
Columella much looser than in the other related species.

Locality and geologic occurrence.—The "silex" bed of the Ta
formation, Tampa, Florida.

Type.—No. 324900, U.S.N.M. (pl. 95, figs. 2, 2*a*.)

Paratype.—No. 324901, U.S.N.M. (pl. 95, fig. 1.)

Paratype.—Wagner Free Institute of Science, Philadelphia
95, fig. 3).

11a. ORBICELLA TAMPÄENSIS var. SILECENSIS, new variety.

Plate 96.

1915. *Orbicella cavernosa* var. *silecensis* VAUGHAN, *nomen nudum*. U. S. Nat.
Bull. 90, p. 18.

Corallum oblong, irregularly convex above; type about 16 cm. lo
11 cm. wide, and 9.5 cm. high.

Calices slightly elevated, the corallites somewhat swollen below the alicular edges. Diameter, 8.5 to 9.5 mm. Costae prominent; those orresponding to the primary and secondary septa subequal; tertiaries ubequal to those of lower cycles or smaller; fourth cycle small but sually recognizable.

Septa in four cycles, usually differentiated in size according to ycle; primaries and secondaries and occasionally some tertiaries reach he columella. Margins of primaries, secondaries, and tertiaries xsert, up to as much as 1.5 mm., usually about 1 mm.; those of the uaternaries obvious but not prominent.

Columella rather well developed.

Locality and geologic occurrence.—The "silex" bed of the Tampa rmation, Tampa, Florida.

Type.—Wagner Free Institute of Science, Philadelphia.

Paratype.—No. 324896, U.S.N.M.

This variety, which intergrades with the typical form of the species, especially distinguished by its less prominent calices and the better eveloped last (quaternary) cycle of costae.

Orbicella tampäensis var. *silecensis* is near *Orbicella costata*, from hich it is separable especially by the more exsert margins of the imary, secondary, and tertiary septa, and by the quaternary septa ving much lower margins than those of the other cycles. The gen- al resemblance of the Tampa specimens of *O. tampäensis* var. *silecen-* is so close to specimens of *O. costata* from Anguilla that at one time thought them referable to the same species, but the differences in e characters of the costae and of the upper septal margins served to parate them. For a comparison of *O. tampäensis* with *O. irradians* (Milne Edwards and Haime) Vaughan see page 394 of this paper.

12. ORBICELLA BREVIS (Duncan).

Plate 97, fig. 1.

1864. *Astraea brevis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 20, p. 37, pl. 4, figs. 3*a*, 3*b*.

1868. *Heliastraea brevis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

1870. *Heliastraea brevis* DUCHASSAING, Rev. Zooph. et Spong. Ant., p. 30.

The following is Duncan's original description:

orallum small, irregularly convex above, and slightly concave below. Corall- is short, irregularly distant, and radiating. Calices circular, tolerably elevated, th r height varying; the margin is rather sharp, and the external wall is marked b very distinct costae. The septa are very slightly exsert, largest at the wall, arched, th radius of the curve being directed upwards and inwards, passing but a little way in ards before descending abruptly; they are dentate on the free margin. In six sy ems of three cycles, with a septum of a fourth in some half-systems; primary se a the largest, the tertiary being small. The laminae are perfect, join the col- um lla by ascending processes, and are slightly granular. Costae well developed, pa ing downwards and outwards from the margin; the primary are equal to the se ndary, and there is some variation in the size of the tertiary; they are dentate,

and appear to be covered with a fine epitheca, and their course is often in a cu
In transverse and vertical sections the costae are seen to project far from the w
and to be marked by oblique and abundant exothecal dissepiments; the tert
costae being much less projecting than the others. The columella is large, lax,
papillary. The fossa is deep. The endotheca is not well developed, but the
sepiments extend to close to the calice. Diameter of calices one-fifth inch [5 m
height of the corallum 9.10 inches [22.5 mm.]. The costae are very marked in
species, and with the papillary columella and short calices distinguish it from
allies; it is related both to *Astraea cylindrica* nob., and to *Astraea cavernosa* Edw
& Haime.

From the Nivajè shale, San Domingo. Coll. Geol. Soc.

Duncan's remarks on the affinities of this coral are correct, a
in a previous paper I referred it to the synonymy of *O. caverno*
The type of the species is represented by plate 97, figure 1.
costae are similar to those of *O. costata*, but the calices are m
smaller. It will be noted in the figure that around the calicu
margins the costae are subequal and that lower down on the coral
limb those corresponding to the last cycle of septa become sma
while the alternate costae become more prominent and extend ou
the intercorallite areas. The costal beading is rather coarse, the
resembling *O. tampaensis*, which has larger calices. As predicti
as to the ultimate fate of coral-names are admittedly hazard
I will only remark that it seems to me from the material availa
for study that *O. brevis* is a distinct species; but a specimen from
"silex" beds near Tampa, Florida, so nearly bridges the gap betw
O. tampaensis and *O. brevis* that doubt is cast on their specific disti
ness. Should the two supposed species ultimately be combi
under one name, of course *O. brevis*, it being the older name, w
persist, and *O. tampaensis* would become either a synonym or w
be reduced to varietal or subspecific rank.

13. ORBICELLA INSIGNIS (Duncan).

Plate 98, figs. 1, 2, 2*a*.

1867 *Heliastraea insignis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24
19, 24, pl. 1, fig. 4.

Original description.—"The corallum is large, and the coral
also; they are wide apart, are circular in transverse outline, and
very equal in size. The wall is stout as regards the septa and cos
but thin in comparison with the diameter of the corallites. The s
are delicate, wide apart, long, slightly thicker at the wall than
where, straight, and the primary septa are hardly any broader t
the tertiary. There are three cycles of septa in the six systems,
rarely a septum of the fourth cycle is noticed in half of a syst
The primary and secondary septa are of equal length, and the tert
extend far in towards the columella. The columella is small.
costae are long, slender, often bent, almost equal, and of about

[1] Geolog. Reichs. Mus. Leiden, ser. 2, vol. 2, pt. 1, p. 29, 1901.

ame thickness as the septa; occasionally a rudimentary costa is een, and is not represented by a septum. The exotheca is inclined nd abundant. The endotheca is very abundant and inclined.

"Diameter of corallites (costae not included) four-tenths inch [10 m.].

"*Loc.* Antiguan Tertiary deposits.

"The large size of the corallites, the low septal number, the long pta and costae, with the small columella and highly developed ndotheca, distinguish this species."

One of Duncan's original specimens, in the Geological Society of ondon, is represented by plate 98, figure 1.

I did not obtain in Antigua any coral definitely referable to *O. signis*.

Regarding the specimens from Serro Colorado, Arube, referred by e to *Orbicella cavernosa*,[1] the following notes will be made (see . 98, fig. 2, 2*a*):

The corallites are circular in cross section, and have a diameter a centimeter, sometimes slightly greater. The distance between em is 3 mm. or even greater. Endotheca and exotheca are very hly developed. The septa are usually 24 in number, alternately ger and smaller, all of the larger reach the columella; occasional all quaternaries. They are thin, but are thickened at the wall fficiently to form a so-called "pseudotheca." There are two speci- ns of this coral from Serro Colorado, one of which is completely icified, and a large portion of the other has undergone silicification. e columella is lax, spongy, and fairly large, occupying about one- ird of the diameter of the corallite cavity. These specimens closely semble Duncan's *Astraea radiata* var. *intermedia*, but have larger rallites; they are very near *O. costata* (Duncan), from which they fer by having thicker and fewer septa and a larger columella; *antillarum* differs by its somewhat smaller corallites; I discover difference from *O. insignis* Duncan.

14. ORBICELLA INTERMEDIA (Duncan).

Plate 97, fig. 2.

1863. *Astræa radiata* var. *intermedia* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 421.

Astraea radiata var. *intermedia* Duncan is, according to its original scription, characterized by "having the third cycle of septa com- te, and a little excess of vesicular endotheca. * * * The riety forms a link between the great astraeans of the Miocene of Antilles and the existing *Astraea radiata* of the Caribbean Sea, *traea antillarum* being closely allied to it." The type-specimen, . 2943, Geological Society of London, is represented by plate 97, ure 2. The diameter of the corallites is about 5 mm., distance tween corallites from 1 to 2 mm. There are in places indications

[1] Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, pp. 32-33, 1901.

of small costae between the larger ones, similar to those of *O. cavern* var. *endothecata*, and there are a few quaternary septa. Colum rather small.

I did not collect any specimen of this species in Antigua. T species to which I am applying the name *O. canalis* is very nea related and may eventually become a synonym. However, primary and secondary septa are more nearly equal in *O. interme* than in *O. canalis*. *O. costata* and *O. insignis* are both very sim to *O. canalis*. O. *costata* has more extended costae, and *O. insig* has larger calices and, in comparison with the size of the cali fewer septa. As suites of specimens adequate for a satisfact study of variation are not available, at least temporarily, the th names, *O. intermedia*, *O. costata*, and *O. insignis* should be treate valid.

Locality and geologic occurrence.—According to Duncan, "Fi the upper Parian of Trinidad (Wall and Sawkins coll.), and the m formation [Antigua formation] of Antigua." The specimen rep sented by plate 97, figure 2, is from Antigua.

15. ORBICELLA GABBI, new species.

Plate 108, figs. 1, 1*a*, 1*b*.

Corallum massive; corallites very large, from 20 to 25 mm diameter, by far the largest corallites of any species of the ge known from the American Tertiary formations. Intercorallite a narrow or as much as 4.5 mm., perhaps more, across.

Septa very numerous, thin, crowded, 106 were counted in corallite represented by plate 108, figure 1a. There are more tha complete cycles. Septal grouping obvious, usually every othe every fourth septum reaches the columella, but in places there seven or eight shorter septa, forming a group, between two l septa.

Columella rather small, only about 2.5 mm. in diameter. En thecal and exothecal dissepiments greatly developed, thin-walle

Locality.—Santo Domingo (Gabb Collection).

Type.—Academy of Natural Sciences of Philadelphia.

16. ORBICELLA IRRADIANS (Milne Edwards and Haime) Vaughan.

Plate 97, figs. 3, 3*a*.

1848. *Phyllocoenia irradians* Milne Edwards and Haime. Comptes Rend., 27, p. 469.

1860. *Phyllocoenia irradians* Milne Edwards and Haime. Hist. nat. Co vol. 2, p. 272.

1868. *Phyllocoenia irradians* Reuss, K. K. Akad. Wissensch. Wien. M Naturw. Cl., Denkschr., vol. 28, p. 156, pl. 10, figs. 5–7; pl. 11, figs.

This appears to be the species referred to by Fabiani in his "paleogene del Veneto"[1] as *Heliastraea irradians* Michelin. Mich erroneously applied the name *Astrea radiata*[1] to this species.

[1] R. Univ. Padova Inst. geolog. mem., vol. 3, pp. 225, 230, 231, 1915.

Figures of *Orbicella irradians* and some notes on it are introduced
re, because of the close resemblance of *Orbicella tampäensis* to it.
he beading of the costae in *O. tampäensis* appears coarser, and
liform lobes seem more specialized in *O. irradians*.

Locality and geologic occurrence.—Milne Edwards and Haime (1857)
cord it from Castel Gomberto and Chaine d'Hala (Sinde). Reuss[2]
ys it is the most abundant anthozoan of the Monte Grumi beds.
also records it from Castellaro, Monte Spiado, Monte del Carrioli,
d Montecchio Maggiore.[3] D'Archiardi mentions it as occurring in
iat he designates as the Castel Gomberto, Montecchio Maggiore,
d Monte Viale groups.[4] Fabiani refers *Heliastraea irradians*, by
ich I believe he means this species, to the Lutetian (Eocene) and
the Rupelian (middle Oligocene) of Castel Gomberto and San
ovanni Ilarione. The specimen in the United States National
iseum (No. 164723) (see pl. 97, figs. 3, 3*a*), was received from
ofessor Parona of the University of Turin, and came from
nte Grumi di Castel Gomberto. Although apparently reported
m the Lutetian Eocene of Veneto, it is most abundant in the
pelian or middle Oligocene. Because of the close resemblance of
icella tampäensis to *O. irradians*, of the presence of *Antiguastrea*
ulosa in the "silex" bed at Tampa, and of the presence at Tampa
species of *Stylophora, Galaxea, Endopachys, Goniopora*, and *Alvec-*
a, all genera now extinct in the Atlantic Ocean, I believe that
fauna of the "silex" bed at Tampa surely is as old as upper
ligocene.

The generic name *Phyllocoenia*, genotype *P. irradians*, is a syno-
n of *Orbicella* Dana.

Genus SOLENASTREA Milne Edwards and Haime.

1848. *Solenastrea* Milne Edwards and Haime, Compt. Rend., vol. 27, p. 494.
1850. *Solenastrea* Milne Edwards and Haime, British fossil corals, Introduction, p. xl.
1917. *Solenastrea* Vaughan, U. S. Geol. Survey Prof. Pap. 98–T, p. 371.

Type-species.—*Astrea turonensis* Michelin.

SOLENASTREA HYADES (Dana).

1846. *A[straea] Orbicella hyades* Dana, U. S. Expl. Exped. Zoophytes, p 212, pl. 10, fig. 15.
1846. *A[straea] Orbicella excelsa* Dana, U. S. Expl. Exped. Zoophytes, p. 212, pl. 10, fig. 16.
1902. *Orbicella excelsa* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 98, pl. 15, figs. 4, 4*a*, 4*b*.

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[1] n. Zoophytol., p. 58, pl. 12, fig. 4, 1842.
[2] K. Akad. Wissensch. Wien, Math.-Natuwiss. Cl. Denkschr., vol. 28, p. 156, 1868.
[3] n, p. 135.
[4] S lio comparativo fra i coralli dei terreni terziari del Piemonte e dell' Alpi Venete, p. 46, Pisa, 1868.

1902. *Solenastrea hyades* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. p. 104, pl. 15, figs. 5, 5*a*, 5*b*.

1917. *Solenastrea hyades* VAUGHAN, U. S. Geological Survey Prof. Paper 98 pp. 372, 373, pl. 98, figs. 1, 1*a*, 2, 2*a*, 3.

Professor Verrill has studied Dana's types of *Orbicella hyades* in t collection of the Boston Society of Natural History, and gives t following description:[1]

Calicles circular, or nearly so, mostly 3 to 3.5 mm. in diameter; borders gener distinctly elevated above the exotheca, often to the height of 0.5 to 1 mm. Your and smaller calicles, 1.5 to 2.5 in diameter, are scattered between the full-gr ones. In the middle of the convex summit the calicles are so crowded that the w are in contact, and here they often become angular by crowding, and when no contact their edges may not be elevated. On other parts they may be separated intervals of 2 or 3 mm. or more. The walls are very thin. The costae are thicke and roughly minutely serrulate; they are very narrow and mostly confined to wall, never extending across the exothecal spaces, when these occur. The sur of the exotheca is smooth or vesicular; in sections the exotheca is openly vesicu

Septa 20 to 24, mostly 24 in mature calicles; 12 extend to the columella; thos the third cycle are also wide, but thinner, and most of them bend toward and the larger ones about midway between the wall and columella. The septa all bec thin and curved toward the columella, but thickened at the wall; the summits narrowed and rather prominent above the walls; inner edge irregularly and rou serrulate, especially distally; sides roughly granulated. Paliform lobes small thin. Columella usually rather small and loose; formed of small twisted proc from the inner edges of the septa, but variable in size.

Thickness of the larger mass from St. Thomas, about 50 mm.; diameter 125 r diameter of calicles, mostly 3 to 3.5 mm., rarely 4 mm.

This species is found on the Florida Reefs and throughout the West Indies has not been found at the Bermudas. St. Thomas (coll. C. F. Hartt, Yale M In the American Museum, New York, there is a large turbinate mass, 12 to 14 in in diameter and about 10 inches high, from Jamaica.

The same author gives the following description of *Orbi excelsa* Dana:[2]

Dana's type of this species, in the Boston Society of Natural History, was care studied by me a number of years ago, and descriptions were made at that time. type is apparently slightly beach-worn, but so little that the natural surface o coenenchyma and costae, and the summits of the septa are well preserved in parts, and there is no evidence of post-mortem alteration by infiltration to ac for the solidity of the coenenchyma, referred to by Dana, and which is, in quite remarkable in most parts. The coral is very solid and heavy as contr with *O. annularis* or *Solenastraea hyades*.

A fragment, apparently of the same specimen, and which appears to have used by Dana in describing the details, is preserved in the Museum of Yale Unive From this the accompanying photograph has been made (pl. 15, fig. 4). The grows in irregular, often upright, lobed or gibbous masses, up to 100 to 150 m more high, but when young it must be encrusting. No. 1729.

The type-specimen is so strongly lobed that the lobules in some places loo incipient branches. But these may possibly be due to the coral growing ov tubes of invading bivalves or annelids, though none can be seen without sec

[1] Conn. Acad. Arts and Sci. Trans., vol. 11, pp. 104, 105, 1902.

[2] Idem, vol. 11, pp. 98, 99, 1902.

e calicles are more closely crowded on the lobules, especially at the obtuse summits, ere they become angular and are separated by thin walls and cellular exotheca. ewhere the calicles are nearly circular, scarcely elevated, and separated by thecal spaces usually about equal to the radii of the calicles, but toward the base n equal to their diameters. The exotheca and walls are very solid in most parts.

he 24 costae are subequal, thickened, only slightly raised, faintly or almost micropically granulated: those of adjacent calicles are usually separated at the surface a slight intermediate groove, forming polygonal areas around the calicles. The theca is nearly level with the edges of the walls and costae, flat or slightly concave, utely granulated or nearly smooth, sometimes slightly vesicular at the surface, usually almost solid and blended with the costae and walls; near the tips costae e and exotheca is cellular.

n a transverse section, near the surface, the entire partition between the calicles be perfectly solid, whether thick or thin, but in many cases one or two rows of ll, rounded or crescent-shaped vesicles can be seen, and sometimes, close to the nce, vesicular dissepiments are visible between the small costae, while close to basal margin of the coral the exotheca may be decidedly vesicular, appearing st like miniature honeycomb in transverse sections. But this basal portion is ed by the thin, down-growing margin, where the new calicles are very short, que, and far apart, as in many other corals that have a thin, proliferous margin.

ne septa are generally 24, subequal, in three regular cycles; those of the first two es are nearly equal in height and thickness; those of the third cycle are thinner narrower, and generally bend to the right and left in pairs to join the straight of the second cycle, usually at a point more than half way to the columella, and very near it. The summits of all the septa are narrow and only slightly raised e the walls. The edges are irregularly serrulate, two to four of the basal teeth the larger. The sides are distinctly granulated. The septa are all thin, but tly thickened toward the wall, and all are narrowed above the base, so as to leave p-like calicular cavity. The columella is small, trabecular, papillose, and often y wanting. In transverse sections of some calicles it is solid, and formed by the n of the inner edges of the septa, but in most it is small, porous, trabecular.

ameter of the calices 2.5 to 3 mm.; breadth of intercalicinal spaces, usually 1 to 2 sometimes 3 to 4 mm. or more, near the base.

gin uncertain, supposed to be West Indies. Several irregular gibbous masses s species, 3 to 5 inches in thickness, in the American Museum, New York, were l near Osprey, West Florida, cast on the beach, after a storm, by R. P. Whit- (No. 485). I have also seen specimens from Key West.

errill keeps *O. hyades* and *O. excelsa* separate, with the remark, ever, that "they may eventually prove to be one species." The rences between the two consist in the latter possessing a much solid exotheca and more developed costae. There is in the ed States National Museum a moderate suite of specimens from iving Florida reefs, and a large number of fossil specimens. I convinced that the two forms are only variations of the same es, as in the same specimen the exotheca may be solid or vesicular; the costae may be confined to the corallite periphery or extend the periphery of one corallite to that of the next. Although ssor Verrill's descriptions are so comprehensive as to render a one unnecessary, I should like to call attention to some features considered in detail by him. The costae seen on the surface

are not prolongations of the distal ends of the septa. They are on elevations on the exothecal surface corresponding in position w the septa. The exotheca is usually built up of more or less horizon platforms, which when closely applied one above another give r to a compact, or even a solid exotheca; if the platforms are separat the intervening spaces contain vesicular dissepiments. In so instances the exothecal surface is formed by thin-walled vesic The septal trabeculae are directed upward at a low angle, and h their courses indicated by rather small and crowded granulatio The inner septal edges or trabeculae from the septal edges fuse form a false columella. The septa usually are imperforate; howev in some instances perforations occur between the trabeculae n the columella, but never so abundantly as in *Orbicella annularis*.

Localities and geologic occurrence.—Recent specimens in the Uni States National Museum: Osprey and Caesars Creek, Florida, c lected by T. Wayland Vaughan; southern Florida, collected by S. Walker; Caesars Creek, Florida, collected by Edw. Palmer; Ce Keys, Florida, collected by Lieut. J. F. Moser, U. S. N.; reefs n Miami, Florida, collected by J. E. Benedict.

Pleistocene, Miami oolite and Key Largo limestone, Florida, c lected by T. W. Vaughan.

In the Pliocene Caloosahatchee marl on Shell Creek and Caloo hatchee River, Florida, collected by numerous persons.

In the Miocene La Cruz marl at stations 3440 and 3443, in northeast part of Santiago, Cuba; station 3445, crossing over railroad of the highway from Santiago to the Morro, collected T. W. Vaughan. At one time I thought these Santiago specim might come from a deposit of Pliocene age, but the other associa fossils indicate that this is another species of considerable geol antiquity. A specimen from station 3451, Cienaga railroad stati near Habana, collected by T. W. Vaughan, seems to belong to t species.

SOLENASTREA BOURNONI Milne Edwards and Haime.

1850. *Solenastrea bournoni* Milne Edwards and Haime, Ann. Sci. nat., se Zool., vol. 12, p. 121.

1861. *Cyphastrea oblita* Duchassaing and Michelotti, Mém. Corall. Anti p. 77 (of reprint).

1861. *Plesiastrea carpinetti* Duchassaing and Michelotti, Mém. Corall. Anti p. 77 (of reprint).

1861. *Solenastrea ellisii* Duchassaing and Michelotti, Mém. Corall. Anti p. 77 (of reprint).

1861. *Solenastrea micans* Duchassaing and Micheloltti, Mém. Corall. Anti p. 77 (of reprint), pl. 9, figs. 10. 11.

1861. *Leptastrea caribaea* Duchassaing amd Michellotti, Mém. Corall. Anti p. 78 (of reprint).

1863. *Plesiastraea distans* Duncan, Geol. Soc. London Quart. Journ., vol. 2 37, pl. 4, figs. 4*a*, 4*b*.

1863. *Plesiastraea globosa* DUNCAN, Geol. Soc. London Quart. Journ., vol. 20, p. 38, pl. 4, fig. 5.

1917. *Solenastrea bournoni* VAUGHAN, U. S. Geol. Survey Prof. Paper 98–T, pp. 372, 374, pl. 99, figs. 1, 1*a*, 1*b*, 2, 3, 3*a*; pl. 100, figs. 1, 2, 2*a*, 3, 3*a*, 3*b*.

he following description is based on specimens from the Pliocene osohatchee marl of Florida:

orallum forming spheroidal or dome-shaped masses, sometimes much as a foot, or even more, in diameter; the outer surface ormly rounded or with gibbosities.

he succeeding portion of the description is based upon a single l-shaped specimen, 15.3 cm. tall; greater diameter 12.8 cm., r, 11 cm.

he calices have very slightly elevated margins, and thin corallite s. Diameter from 2 to 2.5 mm. Distance apart from 0.75 to it 2 mm.; usually about 1 mm., or half the diameter of the es. The depth of the calicular fossae can not be determined with ainty, as the specimen is worn; where it is best preserved they shallow. The corallite walls externally are costate, a costa corponding to each septum; the costae, however, are short, those n one corallite not extending to those of the next. Between the llites are thin-walled exothecal vesicles, which have a horially stratified arrangement. The outermost exothecal platform show costal striations.

he septa are thin, somewhat thicker at the wall; uniformly in e complete cycles; primaries and secondaries equal and reaching columella; tertiaries only about half as long; thinner, inner gins free. Rather wide, thin pali occur before the first and nd cycles. The septal faces are finely granulate, with the ses of the trabeculae indicated; no perforations could be disred. Thin endothecal dissepiments present. Columella poorly loped, rather small and lax.

VARIATION OF SOLENASTREA BOURNONI.

he United States National Museum possesses very large suites of mens of this species, permitting a rather satisfactory study of variation. The specimen already described shows within itself imits of variation in the size and distance from one another of calices. About 2 mm. is the average calicular diameter. The neca may be very light and delicate, or rather compact, even st solid. The septa vary in thickness and the pali may be ngly or weakly developed; where strongly developed they are angular in shape, the base of the triangle directed outward, and he tertiaries may fuse to the basal corners or to the sides of the pali efore the secondaries. The thickened pali are correlated with the ner exotheca, the various skeletal elements seem to thicken ogether.

SYNONYMY OF SOLENASTREA BOURNONI.

Of the species described by Duchassaing and Michelotti, *Cyphastrea oblita*, *Plesiastrea carpinetti*, *Solenastrea ellisii*, *Solenastrea micans*, and *Leptastrea caribæa* can confidently be placed in this synonymy.

I examined in the Museum of Natural History in Turin a specimen labeled *Cyphastrea oblita* Duchassaing and Michelotti, but it is a small caliced corallum of *Orbicella annularis* (see p. 374 of this paper), and it does not accord with the original description of *C. oblita*, which is as follows: "Species rounded, with rounded calices, the margins of which are a little elevated; costae rare, almost confluent, the intercalicular areas are beset with granulations: columella, lamellar and papillary."

In a note it is stated the septa of *C. oblita* bear small, subpalifor lobes. It seems to me more probable that the type is the specimen in the Muséum d'Histoire Naturelle, Paris, figured by me in United States Geological Survey Professional Paper 98–T, plate 99, figures 3, 3*a*.

The original description of *P. carpinetti* is as follows: "The form of the corallum is convex and lobed; the calices are small, and often slightly deformed with prominent margins, separated by distinct costae and vesicular tissue: the septa are finely denticulate and do not attain a length of one-third the radius of the calice because of the development of the pali. The last are thick, as strong as the septa, when examined with a lens they appear covered with granulations; the columella is formed by papillae similarly granulate."

Solenastrea ellisii, according to Duchassaing and Michelotti, "is for a synonym the *Astrea pleiades* figured in the work of Ellis and Solander, Nos. 1 and 4 of plate 53." There is a specimen, probably the type, in the Museum of Natural History at Turin, labeled *Solenastrea ellisii*. It has small calices, 2 mm. in diameter, and three cycles of septa, the members of the last cycle are very small.

The original description of *Solenastrea micans* is as follows: "Corallum orbicular, with crowded calices, circular, but often deformed, diameter about a line [2 mm.]; their upper margin is free, projecting above the rest of the surface; the septa are very echinulate and thicken outwardly; the columella is thick and vesicular." St. Thomas.

The calices of the type are crowded; 2 to 3 mm. in diameter. Septa in two complete cycles, with a few tertiaries; primaries and secondaries of the same size

The original description of *Leptastrea caribaea* is as follows: "Species globular, with calices almost contiguous, circular, margins elevated; columella simple, septa alternately smaller." St. Thomas.

Calices of the type, 2 to 2.5 mm. in diameter: margins slightly elevated. Septa of the last cycle rarely fused to the sides of the

ondaries; paliform lobes insignificant or absent. Columella with illate upper surface.

Duncan's *Plesiastraea distans* and *P. globosa*, from the silt of the dstone plain of Santo Domingo, belong in the same synonymy. e types of both species are preserved in the collection of the logical Society of London, where I have studied them. A dupli- e of the latter is in the United States National Museum. The ference between *P. distans* and *P. globosa* consists in the calices he former being one-half or more than one-half their diameter rt, while in the latter the distance between them is usually less n one-half this diameter.

Cyphastrea hyades and *C. bournoni* are closely related species. The ces of *C. hyades*, however, are constantly larger than those of *bournoni*, and the tertiary septa, except in young coralla, con- tly fuse to the sides of the secondaries. *C. bournoni* has smaller ces. and except when the pali are decidedly thickened, has the r ends of the tertiary septa free. These differences are constant he considerable suites of specimens that I have been able to study.

Localities and geologic occurrence.—Living at St. Thomas, Virgin nds, whence Duchassaing had a number of specimens. Tortugas, rida, in water between 8 and 9 fathoms deep.

Miocene, in the Caloosahatchee marl of Florida, on Caloosahatchee er, collected by Frank Burns and others; and Shell Creek, rida, collected by Frank Burns and by Doctor Griffith.

Miocene, Rio Cana, Zone H, Santo Domingo, collected by Miss . Maury in association with an invertebrate fauna of the age of Bowden marl of Jamaica.

Miocene, in the La Cruz marl, Santiago, Cuba, at stations 3436, 47, 3446, collected by T. W. Vaughan, in association with an rtebrate fauna closely related to, but probably a little younger n that of the Bowden horizon.

ANTIGUASTREA, new genus.

rowth form massive; asexual reproduction by intercorallite ding; septal margins very obscurely dentate, subentire; coral. usually joined by thin costae; columella lamellar, usually well eloped and prominent; exothecal and endothecal dissepiments ly developed.

Type-species.—*Astraea cellulosa* Duncan.

his genus is near *Orbicella*, from which it differs by its more urely dentate septa and its lamellar columella. The costae ween corallites are thin and in some instances disappear on the ace of the exothecal vesicles.

Reis[1] proposed the name *Heterastraea* for the genus here nam *Antiguastrea;* but, as R. F. Tomes had used *Heterastraea* for a ge of English Liassic corals in 1888,[2] Reis's name can not stand. Re account of the columella in his description of *Heterastraea* is cont dictory. Regarding *Heterastraea tenuilamellosa* (Gümbel) Reis, says, "zeigen ein verlängertes blattartiges bis papillöses Säulche The columella in that species, therefore, is lamellate.

This genus of corals is important in its bearing on the correllat of American and European Tertiary formations. At the end of table of the corals from the Reiter Schichten, Reis says:[3] "diesem Tabelle geht unzweifelhaft hervor, dass erstens die Re Korallenlager und die vom Hallthurm mit denen von Haer gänzlich stimmen, also keinen tieferem Horizont angehören kön und dass zweitens dieser Horizont sowohl durch Haeringer Schich als auch durch die deutlichsten Beziehungen zu den unter- bis mi oligocänen Korallenlagern des Vicentins als solcher festgestellt is Reis reports species of *Heterastraea* from Reit, Castelgomberto, Crosara.

There is in the United States National Museum (No. 155186 specimen of *Heterastraea michelottina* (Catullo) Reis, received fr Prof. K. A. von Zittel. This specimen has a distinct, short, thi lamellar columella. It so closely resembles *Antiguastrea cellul* that specific distinction is difficult, perhaps even doubtful. *Isast elegans* Reuss is referable to *Antiguastrea*. It is described after *A guastrea cellulosa* (see p. 409, pl. 102, figs. 1, 1*a*). *Astrea alveol* Catullo[4] also belongs to *Antiguastrea*. Notes on it follow those *A. elegans*.

ANTIGUASTREA CELLULOSA (Duncan).

Plate 98, figs. 3, 3*a*, 4, 4*a*; plate 99, figs. 1, 1*a*, 2, 2*a*, 3, 3*a*; plate 100, figs. 1, 2, 3, 4, 4*a*; plate 101, figs. 2, 2*a*.

1863. *Astraea cellulosa* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, 417, 418, pl. 13, fig. 10.
1863. *Isastraea turbinata* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19 423, pl. 14, figs. 1*a*–1*c*.
1866. *Heliastraea cellulosa* DUCHASSAING and MICHELOTTI, Sup. Mém. Co Antilles, p. 86 (of reprint).
1866. *Isastraea turbinata* DUCHASSAING and MICHELOTTI, Sup. Mém. Co Antilles, p. 89 (of reprint).
1867. *Heliastraea cellulosa* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p
1867. *Isastraea turbinata*, DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p
1870. *Heliastraea cellulosa* DUCHASSAING, Rev. Zooph. et Spong. Antilles, p.

[1] Korallen der Reiter Schichten, Bayerisch. geognost. Landesuntersuch, geognost. Jahreshefte, Jah pp. 150–152, 1889.
[2] Geol. Mag., Dec. 3, vol. 5, pp. 207–218, pl. 7, 1888.
[3] Korallen der Reiter Schichten, p. 94.
[4] Dei terreni di Sedimento superiore delle Venezie, e dei fossili byrozoari, antozoari, e spongiari, ai dannoricetto, p. 54, pl. 11, fig. 1. Padova, 1856.

1870. *Isastraea turbinata* DUCHASSAING, Rev. Zooph. et Spong. Antilles, p. 31.
1902. *Orbicella cellulosa* VAUGHAN, Geol. Soc. London Quart. Journ., vol. 52, p. 497.
1915. *Orbicella cellulosa* VAUGHAN, Carnegie Inst. Washington Yearbook, No. 13, p. 360.

riginal description.—"Corallum tall, and, judging from the dis- tion of the corallites, subplane above. Corallites very numerous, slender, crowded, but distinct; usually cylindrical, but some- es more or less prismatic from mutual pressure; varying in size. transverse section of the corallites is generally circular, now and n deformed. Septa crowded, linear; the primary are the largest, often the secondary are nearly as large. The primary septa are early the same thickness at the wall and throughout. There are systems of four cycles; in imperfectly developed systems the th cycle is wanting, but the persistence of this cycle throughout the systems is very generally decided. The fourth and fifth rs are very small, and when there are only three cycles, the third r is small; the septa are generally straight. Columella small and tly developed. The wall appears to be stout. Costae attached very septum, subequal, and not very greatly developed. Endo- a vesicular, greatly developed. There are often four dissepi- ts dividing each interseptal space. Exotheca cellular and highly loped; exothecal cells small, more rectangular and larger than ndothecal cells. The reproduction is by extracalicular gemma- : the smallest buds visible have three perfect cycles of septa. From the Conglomerate of Antigua. Coll. Geol. Soc.

Dimensions.—Height of corallum several inches. Diameter of lites from 1–2 lines [2 to 4.2 mm.]."

e type of the species was examined in the collections of the ogical Society of London, and the identification of the specimens referring to it was verified.

this is an enormously variable species further discussion of it ld begin with a clear statement of the characters of the typical . These may be summarized as follows: Calices 2 to 4.2 mm. in eter, crowded, but distinct; costae subequal, not greatly devel- e; wall stout. Septa in four cycles, primaries the largest and of the thickness throughout; secondaries almost as large as the pri- s; tertiaries and quaternaries smaller according to cycle. Colu- l said to be small and slightly developed. Endotheca and exo- greatly developed. Plate 98, figures 3, 3*a* illustrate a typical men, which completely satisfies the requirements of Duncan's iption, except that close inspection shows a small, well-developed, late columella. Plate 100, figures 1, 2, are reproduced from graphs of thin sections of specimens and show the lamellar lella.

first variant to be considered is represented by plate 99, figures The corallites have free limbs as much as 1.25 mm. tall, and

are separated by intercorallite areas usually about 1 mm. wide, ra in width from 0.5 to 1.5 mm. The walls are thick; costae slig developed, thin. Calicular diameter from 3 to 5 mm. Septa complete cycles; 6 thick primaries which reach the columella; ondaries stout, but thinner than primaries, reach to or almost to angle formed at the inner ends of the adjacent primaries; terti thin, their inner ends project just beyond a peripheral zone of dis ments; quaternaries small and thin, their inner ends barely reac inner side of the dissepimental zone. Columella a compressed tubercle or an axial lamella. Endotheca and exotheca well d oped. This specimen, which differs only slightly from the ty form of the species, represents the extreme of variation in direction.

One line of variation from the typical form of the species i increase in the size of the calices, diameter from 7 to 9 mm., consequent greater development of the higher cycles of septa, the development of thin corallite walls which are separated by i spaces from 1 to 2 mm. wide. The intergradation between s mens with the large and small calices and thick and thin w corallites is complete; in fact, the variations may be found o same specimen. These larger calicled specimens belong to Duncan designated var. *curvata*.

Specimens showing the variations so far discussed occur in An at the southwestern foot of the limestone hills from Willoughby practically to the intersection of the hills with the sea near Wet Point.

Other lines of variation may best be presented by describ series of specially selected specimens.

Specimen No. 1, from Station 6866, opposite the Cathedral, St. Antigua (pl. 99, figs. 2, 2*a*).—Corallum broken on the base; 66 long, 50 mm. wide, 34 mm. tall. There is one tuberose protube

Corallites separated by narrow intercorallite areas, only 0.25 wide, or by areas which range up to 3.5 mm. across, measured bet the peripheries of neighboring calices. Where the calices are rated the intercorallite areas are depressed and are crossed by costae, which are confluent where they can be clearly seen, b other areas they may alternate; about 15 costae to 5 mm., or th tance between summits of adjacent costae is about 0.3 mm.; the spaces decidedly wider than the thickness of the costae.

The following table gives the size of eight calices.

Measurements in millimeters of calices of Antiguastrea cellulosa.

	1	2	3	4	5	6	7	8
Greater diameter	10.75	9.25	9	9.25	5	7.75	5	
Lesser diameter	10.00	9.25	7.5	6.00	4	6.00	5	

About half the calices on this specimen are 9 or more mm. long. The large calices are usually separated by narrow intercorallite areas, while most of the smaller calices are distant from 1.25 up to as much as 3.5 mm. The large calices are excavated, while the smaller are shallow and are tumid around their peripheries.

Septa thin, normally in four complete cycles; in some calices quinaries are present in a few quarter systems. The primaries are usually somewhat thicker, in a few calices conspicuously thicker than the members of the higher cycles, and extend to the columella; the secondaries also extend to the columella. The tertiaries may fuse to the secondaries near the columella; and the quaternaries may fuse to the tertiaries about halfway between the calicular periphery and the columella, or the inner septal ends may be free. Septal grouping is conspicuous. Septal margins with fine dentations, about 7 in 1 mm.; that is, a little less than 0.2 mm. from the top of one dentation to that of the next.

Columella small, in some calices represented by an axial lamella.

This variant represented by this specimen is abundant about three-quarters of a mile south of the Cathedral in St. John, on the southeast side of the Otto estate, where I obtained 11 specimens.

Specimen No. 2, also from Station 6866, St. John, Antigua (pl. 99, fig. 3, 3*a*).—The corallum is of tuberose shape and has a maximum width of about 75 mm.

This specimen resembles in its characters that part of specimen No. 1 where the corallites and calices are smaller and more distant. The calices are tumid around their peripheries and are shallow. The calicular diameter, measured between the tops of the septal crests, is from 4.5 to 5 mm.; distance between calices, about 2.5 mm. Other characters need not be described, except to say that the columella is either a compressed papilla or a short lamella.

Specimen No. 3, from Station 6856, Friars Hill, Antigua (pl. 100, fig. 3, 3*a*).—The corallum of this specimen is 85 mm. long, 70 mm. wide, about 75 mm. tall, and has a more or less tuberose form of growth.

The fully developed calices are 5 to 6 mm. in diameter, and are usually about 2 mm. apart, with depressed intercorallite areas, and slightly raised calicular rims, which project as much as 0.75 mm. The free part of the corallites in places rises perpendicularly above the intercorallite areas, but in other places the calicular peripheries are rounded in profile.

Septa in four complete cycles, with a few quinaries in some calices; primaries the thickest; secondaries nearly as thick as the primaries; tertiaries considerably thinner; quaternaries the thinnest, unless quinaries are present. There is grouping of the highest cycles around the secondaries, but it is not very striking.

Columella variable in development, represented by an papilla or by a distinct axial lamella.

Other specimens from Station 6866, St. John, Antigua.—' are in addition to those already described, from station two large specimens and fragments representing three others. largest is 13 by 14 cm. in diameter and about 9 cm. tall. The ular and septal characters are similar to those of specimen No the foregoing descriptions. The primary septa in many calic decidedly thick, the thickness of the other septa decreasing acc to cycle. The columella, although it appears to be derived fro septa, is an axial lamella and in many cycles is decidedly thick.

The specimens described in the foregoing remarks are the one have given me the most trouble in identification. They grade di into typical specimens, such as the one on which Duncan bas original description, and those described on pages 403, 404 present discussion.

The following is Duncan's original description of *Isastraea turb*

Corallum 7 inches high, subplane and irregularly convex above, broad and g at the sides, small and conical at the base, whence the corallites radiate; upper ridged with the elevated margins of more or less polygonal, close calices. Cc very long, slender, and prismatic, excessively crowded. Walls united, throughout. Calices very numerous, irregularly pentagonal, not deep, and not geometrically. Margins existing as sharp ridges, not marked by the septa, but ragged; united, crowded, not deep. Septa small, not exsert, not arched, but s irregularly downwards and inwards, except the primary, which stand up in th and are easily seen. They are laminar, delicate, and crowded, slightly tooth the internal end, ragged above, and granular on the sides. The primary sept times meet by their inner ends; the secondary and tertiary are subequal whe are others. They are disposed in six systems. In fully developed calices th four cycles in four systems and three in the rest; in other calices three cycles occasional fourth order. The fourth cycle is very small. Septa straight, not cre but slightly ragged; no external spines. Endotheca tolerably developed. Fi condition of the base, which has been rolled, no epitheca can be seen. Repro by submarginal (close to the wall) gemmation. Diameter of the calices from to 3½ lines [4.2 to 7.3 mm.]. (From the Chert formation of Antigua Coll. Geol.

A specimen that agrees with Duncan's descriptions and figu represented by plate 100, figures 4, 4*a*. This coral puzzled r some time but it is almost typical *Antiguastrea cellulosa*, in the intercorallite tissues have been mineralogically changed so present the appearance of solid intercorallite walls; however, in places the calicular edges persist, showing separate calicular m between which is a lower intercorallite area crossed by thin The septal and columellar characters are precisely as in *A. cel* I failed to find Duncan's type of *Isastraea turbinata* in Londo I am convinced that it is a specimen of *Antiguastrea cellulosa* in the intercorallite tissues are solidified by secondary mineral ch

Localities and geologic occurrence.—This is one of the comm corals in the Antigua formation of Antigua, where I collecte

ught to Washington about 100 specimens. A list of the stations which collected would be almost a list of the exposures of the tigua formation examined. In Cuba, at station 7508, Ocujal ing, altitude 200 feet a. t., near Guantanamo, collected by E. Meinzer. In Porto Rico, zone C, near Lares, collected by Bela bbard, of the New Academy Porto Rican Explorations. Serro orado, Arube, Dutch West Indies.

As a slight variant from the typical form, it is common in the base the Chattahoochee formation along Flint River, near Bainbridge, catur County, Georgia, and it is well represented in the silex bed the Tampa formation at Tampa, Florida.

t is also found in Anguilla, where I collected a single specimen at ion 6893, on the south side of Crocus Bay.

n the State of Tamaulipas, Mexico, at the following localities: mile east of Salitre; Cerro del Aire, 7 miles southeast of Refugio; ile east of San José de las Rusias; hill 4 miles east of San Rafael cimens submitted by Mr. E. T. Dumble).

specimen sent to the United States National Museum by Mr. lip Crutcher is reputed to come from Vicksburg, Mississippi; sequently collected by O. B. Hopkins at station 7463 in the Byram areous marl, 4½ miles south of Vicksburg, Mississippi.

n general, the species is abundant in the three formations men- ed, and is important in indicating an Oligocene horizon. It has yet been found in deposits younger than those of Tampa age.

rof. K. Martin, director of the Geologisch-Reichs Museum, len, submitted to me for determination some material from o Colorado, Arube, that I referred to *Orbicella tenuis* (Duncan), posing at the time that Duncan's *Astraea tenuis* belonged to the s *Orbicella*.[1] Subsequent study of additional collections has vn that Duncan's *Astraea tenuis* is in reality a fungid coral. The wing are the notes I published on the Arube specimens in the er referred to in the footnote:

e corallites are long; are close together, only a millimeter apart, and usually ot round because of having been deformed by mutual pressure; the diameter e corallites is from 4 to 5 mm. The septa are thin, and crowded; the usual gement being four complete cycles. The members of the first and second cycles the columella; those of the third cycle are not so long; and those of the fourth ill shorter. The members of the first and second cycles are of about the same ness, no constant difference in thickness according to cycles is discernible. e is no marked difference in the thickness of any of the septa at the wall. The bers of the third and fourth cycles are slightly thinner. Endotheca is well devel- The exotheca has been destroyed in the process of fossilization. The columella rly developed, being formed by the loose fusion of the principal septa in the space.

also pointed out in the paper cited the close resemblance of specimens described to "*Orbicella*" *cellulosa* (Duncan). I have

[1] Geolog. Reichs Mus. Leiden Samml., ser. 2, vol. 2, p. 33, 1901.

carefully restudied the specimens, and, as I can find only disse
mental endo- and exotheca, they can not be identified as Dunca
Astraea tenuis. Because of silification and changes due to fossili
tion the columellar characters are obscured, but it is possible
recognize the presence of a lamellar columella. The species, th
fore, is definitely *Antiguastrea cellulosa* (Duncan).

ANTIGUASTREA CELLULOSA var. CURVATA (Duncan)

Plate 98, figs. 4, 4*a*.

1863. *Astraea cellulosa* var. *curvata* Duncan, Geol. Soc. London Quart. Jou
vol. 19, p. 418.

Original description.—"Corallites slender, long, close, someti
compressed; circular in transverse section, except when compres
Walls thin and delicate. Costae delicate, unequal, narrow at
base, tapering externally. Septa well developed, in six system
four complete cycles. The primary septa are large, toothed on eit
side, not larger at any one point than at another. The second
septa are smaller than the primary, and have a tooth near
columella. The tertiary are smaller than the secondary, vary m
in size, often extend nearly up to the columella, and curve t
towards the latter; they have lateral teeth, and a larger tooth at
end; or they reach only halfway, being either straight or cur
The quaternary septa have wedge-shaped bases and spike-like
longations, extend one-quarter the distance to the columella,
sometimes curve towards the tertiary. Columella lax and pari
Endotheca greatly developed, subdividing the septal loculi
transverse bars. Exotheca distinct, cells small.

"*Dimensions.*—Diameter of the corallites one-fifth inch [5 mm.
bud 1 line [2 mm.] in diameter has three cycles.

"Chert-formation of Antugua. Coll. Geol. Soc. As a rule,
variety is curiously fossilized."

Plesiotype.—U.S.N.M. No. 324923 (pl. 98, fig. 4, 4*a*). Thi
actually more abundant in Antigua than the typical examples of
species. I doubt the presence of teeth on the primary and second
septa. The appearance of their being present is probably du
changes resulting from fossilization.

ANTIGUASTREA CELLULOSA var. SILICENSIS, new variety.

Plate 101, figs. 1, 1*a*.

The two distinctive characters of this variety are, (1) the fla
domed upper surface; (2) the rather large calices, which are o
sionally only 4 mm. in diameter, but usually 5 to 6.5 mm., someti
the diameter may be as much as 11.5 mm. when the fifth cycl
septa is nearly complete.

Localities and geologic occurrence.—Basal part of the Chattahoo
formation, Blue Springs, Flint River, 4 miles below Bainbridge,

les Landing, Flint River, about 7 miles below Bainbridge, Ga.; lex" bed of the Tampa formation. Specimens obtained about ee-quarters of a mile south of the Cathedral St. John, Antigua, l at station 6893, Crocus Bay, Anguilla, and one specimen from 4 miles south of San Rafael, Tamaulipas, Mexico, are referable to s variety.

Type.—No. 324936, U.S.N.M.

ANTIGUASTREA ELEGANS (Reuss) Vaughan.

Plate 102, figs. 1, 1*a*.

1874. *Isastraea elegans* Reuss, K. K. Akad. Wiss. Wien, Math.-Naturwiss. Cl., Denkschr.,vol. 33, p. 36, pl. 53, figs. 3–5.

1915. *Isastraea elegans* Fabiani, R. Univ. Padova Inst. geolog. mem., vol. 3, p. 230.

llustrations of and a few notes on this species are introduced for poses of comparison with *Antiguastrea cellulosa*. The illustra- is exhibit the calicular characters so well that a detailed descrip- n is not necessary. Specific distinction between it and *A. cellu-* , is exceedingly doubtful.

ocalities and geologic occurrence.—Reuss originally described *straea elegans* from Fontana della Bova di San Lorenzo, the locality which the specimen here figured was obtained. Fabiani lists it as pelian Oligocene.

lesiotype.—No. 156898, U.S.N.M.; specimen received in exchange n Prof. J. Felix of the University of Leipzig.

ANTIGUASTREA ALVEOLARIS (Catullo) Vaughan.

1856. *Astrea alveolaris* Catullo, Terr. sed. sup. Venezie, p. 54, pl. 11, fig. 1.

1874. *Phyllangia alveolaris* Reuss, K. K. Akad. Wiss. Wien, Math.-Naturwiss. Cl., Denkschr., vol. 33, p. 32, pl. 52, figs. 1*a*, 1*b*.

1868. *Phyllangia alveolaris* D'Achiardi, Stud. comparat. corall. terr. terz. Piemonte e Alpi Veneto, p. 20.

1915. *Phyllangia alveolaris* Fabiani, R. Univ. Padova Inst. geolog. mem., vol. 3, p. 231.

his coral is not a species of *Phyllangia*, the type-species of which is *llangia americana* Milne Edwards and Haime,[1] from Florida and h West Indies. I dredged a particularly fine example of *P. ameri-* in water between 15 and 16 fathoms deep in Rebecca Channel, l ida, between Tortugas and Rebecca Light. The columella is p posed of curled, flaky processes from the inner ends of the r cipal septa. The margins of the largest septa are faintly dentate, d e on the septal faces there are small, sharp, distinct ridges with r ulations along their courses.

euss's figures of an enlargement of the calices of *Phyllangia laris* represent the columella as bluntly styliform. He says ever, "Die rudimentäre Axe besteht nur aus 1–3 öfters etwas

[1] Brit. foss. corals, Introduction, p. 44, 1850.

verlängerten Papillen." There are two specimens in the United States National Museum, as follows: (1) No. 156910 from Font della Bova di San Lorenzo, received from Prof. J. Felix; (2) No. 164726, from Monte Grumi, received from Professor Parona of the University of Turin. I believe there is no doubt as to the correctness of the identification of these specimens. The columella in both is lamellate; in No. 156918 a relatively thick, coarse lamella; in No. 164726 it is small and thinner but distinct. *Astrea alveolaris* Catullo, therefore, belongs to the genus *Antiguastrea*, and it closely resembles those variants of *A. cellulosa*, in which the calices are somewhat elevated and relatively remote one from another. Compare especially with the description of specimen No. 2 on page 405 of this paper.

Localities and geologic occurrence.—Catullo originally described the species from "Gambugliano nel Vicentino;" d'Achiardi records it from Dego, Torricelle, Castelgomberto, Monte Viale, Montecchio Maggiore, Crosara, and Veronese; Reuss cites it from Monte di Carlotta; the United States National Museum has it from Font della Bova di San Lorenzo and from Monte Grumi. Fabiani lists the species as of only Rupelian Oligocene age.

Genus STYLANGIA Reuss.

1874. *Stylangia* Reuss, K. K. Akad. Wiss. Wien, Math.-Naturwiss. Cl., Denkschr., vol. 33, p. 11.

Type-species.—*Stylangia elegans* Reuss (K. K. Akad. Wiss. Wien, Math-Naturwiss Cl., Denkschr., vol. 33, 1874, p. 11, pl. 42, figs. 1, 1*a*) from San Giovanni Ilarione. Horizon, Lutetian Eocene according to Fabiani.[1]

The species of coral next to be described does not precisely fit to any of the genera known to me. It has the general aspect of *Antiguastrea alveolaris* (Cat.) Vaughan, and as it has a compressed style or very narrow-lamellate columella, it appeared referable to *Antiguastrea*, but the columella is really more in the nature of a compressed style than a lamella. I should have no hesitancy in referring the species to *Stylangia*, if it were not for the very distinctly developed pali. However, as pali in this group of corals are usually not of generic value I am placing the species in *Stylangia*.

STYLANGIA PANAMENSIS, new species.

Plate 86, figs. 1, 1*a*.

The following is a description of the type, the only specimen of the species well enough preserved to show clearly the specific characters:

Corallum, a small mass, 29 mm. long and 26 mm. wide.

Corallites protuberant from 1.5 up to 3.5 mm., distance between the calicular margins from 2 to 4.5 mm. The diameter at the c

[1] R. Univ. Padova Inst. geolog. mem., vol. 3, p. 226, 1915.

a corallite about 3 mm. tall is about 4 mm., at its base about 5 mm., showing that although the diameter at the base of the free rallite limbs is greater than it is at the calice, the increase in diame- toward the base is rather slight. The costae on the free limbs e low, subequal, closely crowded, between 40 and 48 in number, latively thick, as thick as or thicker than the intercostal furrows, d closely beaded along the edges. The walls are thick.

Septa, 3 complete cycles and a variable number of quaternaries. e 6 primaries are larger than the other septa, extend to the colu- lla, and bear paliform thickenings which are decidedly prominent those calices where they have been preserved; the secondaries are newhat shorter than the primaries; the tertiaries still shorter; and quaternaries, which may be completely developed in some sys- ns, are still smaller; in some systems in many calices the quater- ies are not distinguishable within the calices, but are represented small costae.

Columella, a narrow, compressed style.

Endotheca and exotheca, details of their character not clear in type.

Locality and geologic occurrence.—Canal Zone, station 6016, in the perador limestone, quarry, Empire, collected by T. W. Vaughan d D. F. MacDonald.

Type.—Cat. No. 324955, U.S.N.M.

Genus SEPTASTREA d'Orbigny.

1849. *Septastrea* D'ORBIGNY, Notes sur Polyp., p. 9.
1849. *Septastrea* MILNE EDWARDS and HAIME, Ann. Sci. nat., ser. 3, Zool., vol. 12, p. 163.
1857. *Septastraea* MILNE EDWARDS and HAIME, Hist. nat. Corall., vol. 2, p. 449.
18—. *Septastraea* (part) DE FROMENTEL, Intr. Étude Polyp. foss., p. 174.
1884. *Septastraea* (part) DUNCAN, Linn. Soc. London Journ., Zoology, vol. 18, p. 103.
1887. *Glyphastraea* DUNCAN, Geol. Soc. London Quart. Journ., vol. 43, pp. 24–32, pls. 1–3.
1888. *Septastraea* HINDE, Geol. Soc. London Quart. Journ., vol. 44, pp. 200–227, pl. 9.
1900. *Septastraea* GANE, U. S. Nat. Mus., Proc. vol. 22, p. 194.
1904. *Septastrea* VAUGHAN, Maryland Geological Survey Miocene, p. 444.

Type-species.—*Septastrea subramosa* d'Orbigny, 1849 = *S. forbesi* Milne Edwards and Haime, 1849 = *Astrea marylandica* Conrad, 1841 = *Septastrea marylandica* (Conrad) Vaughan, 1904.

SEPTASTREA MATSONI, new species.

Plate 86, figs. 6, 6a.

Corallum incrusting surfaces of shells. The type incrusts part of the surface of a *Turritella* shell. It is probable that the fully grown corallum may be massive or ramose.

Calices irregular in form, subpolygonal or more or less elliptical in outline; slightly excavated. Diameter from 3 to 4.5 mm.; de about 1 mm. Intervening walls narrow, acute.

Septa in two complete cycles. The primaries are rather thick reach the calicular center; in fully developed calices all or nearly of the secondaries also extend to the center, tertiary septa absen very rudimentary. Margins not exsert; within the calices stra or slightly concave upward. There are no recognizable dentati but on the septal edges and faces there are many rather large gr lations. Interseptal loculi wide and open.

Columella false, formed by the fusion of the thickened inner e of the principal septa. There are no trabecular septal processes.

Asexual reproduction by intercorallite budding.

Locality and geologic occurrence.—Republic of Colombia, sta 7873, Gatun formation, about 0.5 km. west of Usiacuri, collecte G. C. Matson.

Type.—No. 324956, U.S.N.M.

Septastrea matsoni closely resembles young coralla of *S. m landica* (Conrad) Vaughan, from the St. Marys and Yorktown fo tions in Virginia.[1] It is interesting to find in Colombia a speci *Septastrea* that is doubtfully distinguishable from a species in Miocene of Virginia. The fossiliferous marl that almost surro Usiacuri appears to be the same formation as the Gatun formatio to be a part of the Gatun formation. Although the evidence plied by this coral is not great, it is at least indicative of the Miocene age of a part if not all of the Gatun formation.

Family FAVIIDAE Gregory.

Genus FAVIA Oken.

1815. *Favia* Oken, Lehrb. Naturgesch., Th. 3, Abth. 1, p. 67.
1857. *Favia* Milne Edwards and Haime, Hist. nat. Corall, vol. 2, p. 426.
1902. *Favia* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 88.
1917. *Favia* Vaughan, Carnegie Inst. Washington Pub. 213, p. 100.

Type-species.—*Madrepora fragum* Esper.

FAVIA FRAGUM (Esper).

1795. *Madrepora fragum* Esper, Pflanzenth., Fortsetz., p. 79., pl. 64, figs. 1
1901. *Favia fragum* Vaughan, Geol. Reichs Mus. Leiden Samml., ser. 2, vol 34 (with synonomy).
1901. *Favia fragum* Vaughan, U. S. Fish Com. Bull. for 1900, vol. 2, p. 303,
1902. *Favia fragum* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, pl. 13, figs. 1, 2.
1915. *Favia fragum* Vaughan, Washington Acad. Sci. Journ., vol. 5, p.
1916. *Favia fragum* Vaughan, Carnegie Inst. Washington Yearbook No. 1 224, 227.

[1] See Vaughan, T. W., Anthozoa, Maryland Geol. Survey, Miocene, pp. 444–447, pl. 126, figs. 1 pl. 127, figs. 1–3; pl. 128, figs. 1, 2; pl. 129, 1904.

This species is common in Pleistocene deposits near Colon, Canal ne.

Localities and geologic occurrence.—Canal Zone stations 5850 and 37; Pleistocene, Mount Hope, collected by D. F. MacDonald. roughout the West Indies, in Florida, and on the Atlantic side of ntral America, where there are elevated Pleistocene reefs. Now ing throughout the same area, in the Bermudas, the Azores (Quelch), d St. Vincent (collected by Mr. Cyril Crossland, specimens do- ted to the United States National Museum by Prof. J. Stanley rdiner).

FAVIA MACDONALDI, new species.

Plate 102, fig. 2; plate 103, fig. 1.

Corallum massive, with a rounded upper surface (for general ject of the upper surface (see pl. 102, fig. 2).

Calices large, oblong, elliptical or subquadrangular in outline; sepa- ed by intercorallite areas from 2 to 5 mm. across. Cavities slightly cavated. Walls thin on the upper edge, in places entirely composed dissepiments; deeper down fairly thick.

Measurements, in millimeters, of calices of Favia macdonaldi.

e	1	2	3	4	5	6	7	8
ter diameter	11.5	9.75	10.5	15.5	14.5	13	13.5	11
er diameter	11.5	8.5	9.5	8	11.5	12	12	9

The number of septa in calice No. 4 of the table is about 38, of which or 13 extend to the columella. A few rudimentary septa may have n broken so as not to be distinguishable now. In calice No. 5, septa were counted, of which about 12 extend to the columella. a polished cross section, in which every septum is clearly visible, re are 31 septa in a corallite having calicular diameters of 12.5 l 8.5 mm.; of the septa about 12 reach the columella—that is, usu- every alternate or every third septum extends to the columella. the calice the septa are thin and distant, but deeper down they are her thick. The inner ends of the long septa are slightly thickened, gesting that paliform lobes were present.

Costae correspond to all septa, greatly developed, long; those m one corallite extending to meet those from the adjacent corallite; mbers of the different cycles subequal in thickness; thicker in the ll, gradually thinning distally.

Columella composed of the fused inner ends of the septa; fairly l developed; some papillae on upper surface.

Thin endothecal and exothecal dissepiments well developed.

No clear instance of asexual reproduction was observed, but that s by fission seems an inference warranted by the configuration of corallites.

Locality and geologic occurrence.—Station 6587, in limestone
iron bearing sandstone, Tonosi, Panama, collected by D. F. M
donald. This deposit is of Oligocene age (for fuller discussion,
pages 207, 555, 582). Station 6881, Antigua formation, Willoug
Bay, Antigua, collected by T. W. Vaughan.

Type.—Cat. No. 324993, U.S.N.M.

The only American fossil species at all nearly related to *F.*
macdonaldi is one from the Oligocene or Miocene of Santo Domi
not yet described in print. It has smaller corallites and relati
more numerous septa than *F. macdonaldi*. These two species are I
Pacific in their affinities, there being no nearly related specie
the Atlantic Ocean, with the possible exception of *F. leptoph*
Verrill, of which I have no specimen for comparison. It gives
pleasure to attach the name of Doctor Macdonald to this re
handsome species of coral, which was discovered by him.

Genus FAVITES Link.

1807. *Favites* Link, Beschreib. Nat. Samml. Rostock, pt. 3, p. 162.
1901. *Favites* Vaughan, Geolog. Reichs Mus. Leiden Samml., ser. 2, vol. 2,
1902. *Favites* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 92.
1917. *Favites* Vaughan, Carnegie Inst. Washington Pub. 213, p. 109.

Type-species.—*Madrepora abdita* Ellis and Solander.

FAVITES MEXICANA, new species.

Plate 103, figs. 2, 2*a*.

Corallum massive, with more or less rounded or flattish u
surface. Type a small broken specimen, 54 by 61 mm. in horizo
diameter and 27 mm. thick.

Corallites polygonal, separated by narrow intercorallite walls w
are barely 0.5 mm. thick. Diameter of corallites as follows:

Diameter, in millimeters, of corallites of Favites mexicana.

Corallite	1	2	3	4	5	6	7
Greater diameter	9	11	8.5	8.5	9	7.5	11.5
Lesser diameter	7.5	7.5	8	7.5	7.5	6.5	9

Calices damaged so that their depth can not be definitely as
tained, but apparently they were shallow.

There are 46 septa in a corallite 7.5 by 6.5 mm. in diameter
these, 14 reach the columella and 23 are small or rudiment
Usually three sizes of septa are recognizable; the tertiaries fus
the side of the secondaries, as a rule. Even the large septa
relatively thin, not so thick as the width of the interseptal lo
The inner ends of the principal septa are somewhat thickened
paliform lobes may have been present.

Columella trabecular, false, fairly well developed.
Thin endothecal dissepiments abundant.
Asexual reproduction by marginal fission.
Locality and geologic occurrence.—Mexico, hill 4 miles east of San Rafael Ranch, State of Tamaulipas, collected by W. F. Cummins and J. M. Sands in the Oligocene San Rafael formation of Dumble,[1] in association with *Antiguastrea cellulosa* (Duncan) Vaughan.
Type.—Cat. No. 324995, U.S.N.M.

This specimen closely resembles *Astroria antiguensis* Duncan.[2] I have a photograph (see pl. 131, fig. 4) of Duncan's type (No. 12936, Brit. Geol. Soc. London), and because of the resemblance, I furnished to Dumble the name *Goniastrea (?) antiguensis* (Duncan), as given in his papers cited. Subsequent study of the photograph and further comparisons with specimens from Antigua lead me to believe that *Astroria antiguensis* is in reality a fungid coral, and is probably based on a silicified specimen of *Cyathomorpha antiguensis* (Duncan) Vaughan in which the corallites are deformed by crowding. That adjacent corallites are separated by costate intercorallites areas is clear on most of this photograph; and apparently there are both intercostal and mural synapticulae. For additional notes on *Astroria antiguensis* see page 466 of this paper.

FAVITES POLYGONALIS (Duncan).

1863. *Astroria polygonalis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 424, pl. 14, fig. 6, 1863.

Besides *F. mexicana*, the only other definitely known species of *Favites* in the American older Tertiary formations is *F. polygonalis* (Duncan) Vaughan, which is very abundant in Antigua. The calices of *F. polygonalis* are much larger than in *F. mexicana*, the smallest usually being 15 mm., rarely as little as 14 mm. in diameter; range in diameter from the size just stated up to 23 mm. wide by 30 mm. long, an extraordinarily large calice. The lesser diameter of calice is usually between 15 and 20 mm. The calices are excavated, depth 8 to 10 mm., separated by acute walls. Septa in 4 cycles, thin, rather distant, about 8 within 1 cm. In many specimens there is a more or less flattened zone around the columella fossa, which is bounded by the rather steep inner ends of the septa. In *F. mexicana*, 9 septa were counted within a linear distance of 5 mm., being twice as many within the same distance as there are in *F. polygonalis*. Cooke and Mansfield collected in the beds of the Chattahoochee formation, station 7078, 8 miles below Alum Bridge, Georgia, a species of *Favites* that seems to be the same as the Antiguan specimens of *F. polygonalis* with small calices.

[1] See p. 206 for additional notes.
[2] Geol. Soc. London Quart. Journ., vol. 19, p. 425, 1863.

Genus GONIASTREA Milne Edwards and Haime.

1848. *Goniastrea* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 4

Type-species.—*Astrea retiformis* Lamarck.

GONIASTREA CANALIS, new species.

Plate 91, fig. 4.

Corallum massive, rounded or flattened on the upper sur forms masses 15 cm. or more in diameter.

Calices joined directly by their walls, shallow, polygonal defor lesser diameter of adult calices about 3.5 mm., greater diameter 3.5 mm. up to 5.5 mm.

Septa about 42, in a calice 3.5 mm. wide by 4 mm. long; of t 11 extend to the columella, and there are about 21 small (ra rudimentary) septa. The inner ends of the smallest septa are usu free; but the septa of the intermediate size fuse to the sides of members of lower cycles, and in places a small septum fuses to side of a member of a lower cycle. As is normally the case in c reproducing by fission, the septal arrangement is not definite. A 10 septa, alternately larger and smaller, were counted in a spa 2.25 mm. along the wall. At the wall the interseptal spaces about as wide as the thickness of the larger septa. Septal f with some granulations. Septal margins too badly damage permit a study of their characters.

Columella false, fairly well developed, formed by the fusion o inner end of the long septa.

Asexual reproduction by fission, either equal or unequal, e fission seems more common.

Locality and geologic occurrence.—Canal Zone, station 6016, qu Empire, in the Emperador limestone collected by T. W. Vau and D. F. MacDonald.

Type.—No. 324996 U.S.N.M.

Of the species of *Goniastrea* previously described from the Ame Tertiaries, *G. variabilis* Duncan[1] from the upper Eocene St. tholomew limestone, French West Indies, has larger calices, ab mm. wide, and as it has about 40 septa to a calice, the septa in less crowded than in *G. canalis*. I collected in the Oligocen Antigua, in the Antigua formation, a species of *Goniastrea*, th evidently the same as *Stephanocoenia reussi* Duncan.[2] This differs *G. canalis* only by the absence of rudimentary septa betwee larger septa. The two forms, although closely related, see represent distinct species.

[1] Geol. Soc. London Quart. Journ., vol. 29, p. 557, pl. 21, fig. 11, 1873.

[2] Idem, vol. 24, p. 19, pl. 2, fig. 1, 1867. I have excellent photographs of Duncan's type, whic 5011, Brit. Mus. Nat. Hist.

Genus MAEANDRA Oken.

1815. *Maeandra* OKEN (part), Lehrb. Naturg., Th. 3, Abth. 1, p. 70.
1902. *Maeandra* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 66.
1917. *Maeandra* VAUGHAN, Carnegie Inst. Washington Pub. 213, p. 119.

Type-species.—*Madrepora labyrinthiformis* Linnaeus.

MAEANDRA ANTIGUENSIS, new species.

Plate 103, figs. 3, 4, 4*a*.

The general habit of the corallum is similar to that of *Maeandra osa* (Ellis and Solander), that is, the upper surface is more or less ılate, not rather uniformly rounded or domed as *M. strigosa* na). A view of the upper surface of each cotype is shown on e 103, figures 3, 4. Valleys sinuous, relatively long, as much as nore than 26 mm. in length; width from 3.5 to 5.5 mm., about 5 mm. usual; depth about 2 mm. Collines with narrow, acute or acute summits, the septa sloping away at an angle of about 45°. acent valleys are usually separated by simple walls; in places arate mural edges are distinguishable, but in such instances the ance between the walls is less than 0.5 mm.

epta decidedly crowded, 8 or 9 long septa and as many interme- e short septa within 5 mm., that is, from 32 to 36 septa, alternately rt and long, within 1 cm. The long septa extends to edge of the mellar fossa; the intermediate septa are about half as long. tal margins finely dentate, about 10 small teeth on the long septa; e downward and inward at an angle of about 45°, as previously ed. Inner ends of long septa more or less thickened, some appear ear paliform lobes, fused by lateral expansions and processes at edge of the columellar fossa.

olumella composed of axial septal processes, which are usually e or less flattened and curled. Calicinal centers indistinct.

hin, crowded, endothecal dissepiments abundant.

ocalities and geologic occurrence.—Antigua, station 6881, Antigua nation, Willoughby Bay, cotypes, 2 specimens, collected by V. Vaughan.

anama, station 6587, Tonosi, a broken specimen, collected by . MacDonald.

otypes.—No. 325003, U.S.N.M.

Maeandra antiguensis is very close to *M. clivosa*. The principal ferences seem to be the steeper margins and the thicker inter- allite walls, and the slightly wider and deeper valleys of *M. isa*. The cotypes of *M. antiguensis* were compared with 33 small mens of *M. clivosa* and the differential characters indicated ar valid.

he specimen obtained by Doctor MacDonald is only a fragment, as the cross-section of the corallites and walls and the septal

characters agree with *M. antiguensis*, there is no reasonable doubt as to its belonging to that species.

MAEANDRA PORTORICENSIS, new species.

Plate 107, figs. 1, 1*a*.

Corallum massive, composed of long valleys, from 5.5 to 9 mm. wide, and about 3.5 mm. deep, separated by acute collines. Walls in the collines, rather thick but simple.

Septa, rather thick, crowded, about 10 in 5 mm., or 20 to the centimeter. As a rule alternately shorter and longer, but in some places they are equal. At the wall usually equal in thickness. The inner ends of some septa are enlarged, and there are indications that such septa bear upright paliform teeth. Margins dentate. Calicinal centers indistinct.

Columella absent.

Locality and geologic occurrence.—Four miles west of Lares, Porto Rico, Pepino formation, collected by R. T. Hill.

Type.—No. 325004, U.S.N.M.

Remarks.—*Maeandra portoricensis* is very close to an undescribed species from the St. Bartholomew Eocene, to which Duncan erroneously applied the name *Manicina areolata* (Linnaeus). The difference seems to lie in the former having straighter valleys (a character of very little value), and thicker septa and walls.

MAEANDRA DUMBLEI, new species.

Plate 104, figs. 1, 1*a*.

Corallum massive, upper surface gradually curved, without prominosities. The type, a segment of a head, is 63 mm. long, 57 mm. wide, and 45 mm. thick.

Valleys straight or curved; length from 5 mm., the diameter of a solitary calice, up to 30 mm. or even more; width from 3 to 5 mm.; depth 1.5 mm. or less, the valleys are very shallow, almost superficial Collines flat or furrowed along the top; width from 1.5 to 5 mm. Each of two adjacent series usually with its own separate wall, the walls separated on top by a slight depression which is crossed by costae. The colline characters are those characteristic of *Diploria*, which is typical *Maeandra*.

Septa rather distant, 9 within 5 mm. or 18 to 1 cm.; subequal or alternately longer and shorter, the shorter usually almost reaching the columella; no rudimentary septa except in young calices; outer septal ends thick. Septal margins broken in the type, but the trabeculae indicate fairly large dentations, about 5 on a lobe; septum outside the distinct, thickened, palar lobe.

Columella composed of septal processes, only slightly developed. Calicinal centers distinct or obscure.

Locality and geologic occurrence.—Mexico, hill one mile east of n Jose de las Rusias ranch, State of Tamaulipas, collected by W. F. mmins and J. M. Sands, in the Oligocene formation to which . E. T. Dumble[1] applied the name "San Fernando beds," later anged to San Rafael beds. *Antiguastrea cellulosa* (Duncan) ughan was also collected at this locality.

Type.—No. 325005, U.S.N.M., presented by Mr. E. T. Dumble.

This species groups with the living West Indian *Maeandra labyrinthi-mis* (Linnaeus), the genotype, which has far more crowded septa, l with *M. bowersi* Vaughan, from Carrizo Creek, California, which wider intercorallite areas, deeper valleys, and fewer long septa the centimeter.

MAEANDRA AREOLATA (Linnaeus).

1758. *Madrepora areolata* LINNAEUS, Syst. Nat., ed. 10, p. 795.
1901. *Manicina areolata* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 305, pl. 4, figs. 2, 3.
1902. *Maeandra areolata* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 81, pl. 11, figs. 1, 2; pl. 12, figs, 1, 2, 3.
1915. *Maeandra areolata* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 596.
1916. *Maeandra areolata* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, pp. 225, 227.

ommon in the Pleistocene marl of Mount Hope near Colon, nal Zone.

ocality and geologic occurrence.—Canal Zone, stations 5850 and 9, Mount Hope, collected by D. F. MacDonald.

his species is a common fossil in the Pleistocene coralliferous osits and in areas of living reefs in the Caribbean region and rida. *M. areolata* is not a true reef coral. It thrives best on flats behind the reefs or in water 10 to 12 fathoms deep off reefs proper. As it has no firm basal attachment, it can not st the impact of the waves of rough seas.

MAEANDRA CLIVOSA (Ellis and Solander).

1786. *Madrepora clivosa* ELLIS and SOLANDER, Nat. Hist. Zooph., p. 163.
1901. *Platygyra clivosa* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 57. (With synonymy.)
1902. *Maeandra clivosa* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 78.
1902. *Maeandra agassizi* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 80, pl. 14, figs. 1, 1*a*.
1915. *Maeandra clivosa* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, pp. 596, 597.
1916. *Maeandra clivosa* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, p. 227.

ocality and geologic occurrence.—Costa Rica, station 6251, Monkey Pt, in a slightly elevated Pleistocene reef, collected by D. F. Mac-

[1] mble, E. T., Some events in the Eogene history of the present coastal area of the Gulf of Mexico in as and Mexico, Journ. Geol., vol. 23, pp. 481, 498, 1915 (see pp. 495–496); Tertiary deposits of northeast Mexico, Calif. Acad. Sci. Proc., vol. 5, pp. 163–193, pls. 16–19, Dec., 1915 (see pp. 189–190).

Donald. This species is general in the elevated Pleistocene re and in the areas of living reefs in the Caribbean region and in Flori It is one of the most abundant species on the living Bahamian re but appears not to occur in the Bermudas.

MAEANDRA STRIGOSA (Dana).

1846. *Meandrina strigosa* DANA, U. S. Expl. Exped. Zooph., p. 257, pl. 14, 4*a*, 4*b*.
1901. *Platygyra viridis* VAUGHAN, Geolog. Reichs. Mus. Leiden, ser. 2, vo p. 51. (With synonymy.)
1901. *Platygyra viridis* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. pls. 9, 10, 11, 12, 13.
1902. *Maeandra cerebrum* VERRILL, Conn. Acad. Arts and Sci. Trans., vol p. 74, pl. 10, fig. 4; pl. 12, fig. 4; pl. 14, figs. 4, 5.
1902. *Maeandra viridis* VAUGHAN, Biol. Soc. Washington Proc., vol. 15, p. 55.
1907. *Maeandra cerebrum* VERRILL, Conn. Acad. Arts and Sci. Trans., vol p. 169.
1915. *Maeandra strigosa* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p.
1917. *Maeandra strigosa* VAUGHAN, Carnegie Inst. Washington Yearbook No p. 227.

I can not at all agree with Professor Verrill's application of I and Solander's name "*cerebrum*" to this species. There are th large, massive species of *Maeandra* in the West Indies and Flor namely, *M. labyrinthiformis* (Linnaeus), *M. clivosa* (Ellis and So der), and *M. strigosa* (Dana). I applied to *M. strigosa* a vari name proposed by Le Sueur, but Professor Verrill expressed do as to Le Sueur's having meant the species under considerat There is good evidence that Ellis and Solander did not intend *Ma pora cerebrum* for this species, for they applied the name *Madrep labyrinthica* to it and figured it. As they applied names to two of identifiable species, it is probable that they intended *Madrep cerebrum* for the third species, that is, for *Madrepora labyrinthifor* of which *Diploria cerebriformis* (Lamarck) M. Edwards and Ha is a synonym.

Under these circumstances, the proper course to pursue evide is to take the first name concerning which there is no doubt. Ch then fall on *Meandrina strigosa* Dana, the type of which is in United States National Museum.

Locality and geologic occurrence.—Costa Rica, station 6251, Mor Point, in the slightly elevated Pleistocene reef, collected by D. F. M Donald. This species is general in the Pleistocene and living c reefs of the Caribbean region, Florida, and the Bahamas, an found living in the Bermudas. It is one of the two most impor massive reef-building species in Florida and the West Indies; other of the most important species is *Orbicella annularis* (Ellis Solander).

Genus LEPTORIA Milne Edwards and Haime.

1848. *Leptoria* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 493.
1917. *Leptoria* Vaughan, Carnegie Inst. Washington Pub. 213, p. 117.

ype-species.—*Meandrina phrygia* Lamarck = *Madrepora phrygia* s and Solander.

LEPTORIA SPENCERI, new species.

Plate 109, figs. 2, 2*a*, 3.

863. *Maeandrina* species Duncan, Geol. Soc. London Quart. Journ., vol. 19, p. 424.

orallum more or less explanate, with a flatish, undulate upper ace.

alleys long and sinuous, shallow, from 3.25 to 5 mm. wide, rated by narrow, but strong colline walls.

here are 8 or 9 long septa within 5 mm., 18 to 19 within 1 cm. se are rather stout and extend from the wall to the columellar a; somewhat thickened in the wall and on their inner ends, where e appear to be paliform knots or lobes. Usually between each of larger septa is a very thin septum, which is either short or long. he columella is stout and lamelliform.

ocality and geologic occurrence.—Cuba, station 3473, Rio Canapu, sing of Manassas trail, Oriente Province, Cuba, collected by Dr. ur C. Spencer, for whom the species is named. *Cyathomorpha is* (Duncan) was obtained at the same place. The geologic zon, therefore, seems to be that of the Antigua formation of gua; but Dr. J. A. Cushman reports *Orthophragmina* from the e station, and suggests that the formation exposed there is of r Eocene age.

he specimen from Antigua referred to by Duncan as "*Maeandrina* seems to belong to *L. spenceri*, according to two photographs I of Duncan's original specimen, No. 12946, coll. Geol. Soc. lon. Duncan's specimen has a distinctly lamellate columella.

ype.—No. 324968*a*, U.S.N.M. (pl. 109, figs. 2, 2*a*).

ratype.—No. 324968*b*, U.S.N.M. (pl. 109, fig. 3).

here is no other known species from the West Indies to which *L. eri* is nearly related. It has closer affinities with the Indo-ic species *L. phrygia* and *L. gracilis*. *L. spenceri* has about the number of septa to the centimeter as *Maeandra antiguensis*, but ffers from *M. antiguensis* in having shallower valleys, stouter serial walls, and its columella is distinctly lamelliform.

Genus MANICINA Ehrenberg.

834. *Manicina* Ehrenberg, Corallenth. Roth. Meer., p. 101 (of reprint).
848. *Colpophyllia* Milne Edwards and Haime, Comptes Rend., vol. 27, p. 492.
902. *Manicina* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 84.

pe-species.—*Madrepora gyrosa* Ellis and Solander.

MANICINA GYROSA (Ellis and Solander).

1786. *Madrepora gyrosa* Ellis and Solander, Nat. Hist. Zooph., p. 163, pl
figs. 1, 2.
1901. *Colpophyllia gyrosa* Vaughan, Geolog. Reichs-Mus. Leiden, ser. 2,
2, p. 41 (With synonymy, except *Mussa fragilis* Dana).
1902. *Manicina gyrosa* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p
1915. *Manicina gyrosa* Vaughan, Washington Acad. Sci. Journ., vol. 5, p.
1916. *Manicina gyrosa* Vaughan, Carnegie Inst. Washington Year Book, N
p. 227.

Locality and geologic occurrence.—Canal Zone, station 5850, P
tocene, Mount Hope, collected by D. F. MacDonald.

Costa Rica, station 5884*b*, probably Pleistocene, Moin Hill,
lected by D. F. MacDonald.

This species is general in the elevated Pleistocene and on the li
coral reefs of the Caribbean area and in Florida. Usually specin
are not abundant, but can nearly always be found in both the P
tocene and living reefs.

There is in the Antigua formation of Antigua a very hands
species of *Manicina,* which is of interest in showing the presenc
the genus in American Tertiary deposits of middle Oligocene a

MANICINA WILLOUGHBIENSIS, new species.

Plate 104, figs. 2, 2*a*; plate 105.

Corallum attached by a more or less centrally placed basal pedu
from which the lower surface slopes upward and outward, upper
face curved or flattish. Common wall thrown into rounded
rugations, which are narrow at the lower end, but widen with
ward growth until they may be 15 mm. across, height as much
mm. Besides the corrugations, the lower surface is costate; l
low rounded costae about 1 mm. apart, with an intermediate sm
costa between each pair of larger. There is no vestige of epith
(There are only occasional shreds of epitheca on the lower su
of *M. gyrosa.*)

Valleys long and sinuous; from 7 to 16 mm. wide, betwee
and 11 mm. usual; depth 8 to 10 mm. Colline submits nar
usually from 1 to 1.5 mm. wide, but the walls of adjacent serie
nearly always distinct, being separated by a narrow furrow, ag
the sides of which the outer ends of the septa terminate.

Septa from 19 to 22 to 1 cm., one-half of which are small
rudimentary; the larger septa are thin and are arranged in 2,
4 sizes. Near the top of the wall all septa are narrow and s
through a distance of about 3 mm., below which the larger s
widen by a slope of about 45°; their inner edges fall steeply, in p
perpendicularly, to the bottom of the axial furrow. There a
definitely developed paliform lobes, but in places the septal ma
rise upward just outside the steep fall into the axial fossa. D

ns on the septal margins small and serrate, not prominant. Septal
es with small granulations.
Columella very poorly developed or absent; calicinal centers as a
e fairly distinct, range from 9 to 21 mm. apart.
Thin endothecal dissepiments well developed.
Locality and geologic occurrence.—Antigua, station 6881, Wil-
ghby Bay, (cotypes), and at other localities in the Antigua forma-
n, Antigua, collected by T. W. Vaughan,
Type.—No. 325006*a*, U.S.N.M.
Paratype.—Cat. No. 325006*b*, U.S.N.M.
This species is closely related to the living *Manicina gyrosa* of the
ibbean and Floridian regions. It has narrower collines, because
septa are narrow in their upper part; it has much more numerous
a; and the septa of *M. gyrosa* have far more exsert-margins.
he only European species, known to me, with which comparison
be made is *Diploria intermedia* Michellotti from the Oli-
ne of Sassello, Liguria (specimen so labelled, received from
Museum of Natural History at Turin, No. 156300, U.S.N.M.).
specimen, although it has the aspect of *Diploria* (precise synonym
pical *Maeandra*), is in my opinion really a species of *Manicina*, for
lower surface is corrugate and there is no epitheca, while there
complete, concentrically striate epitheca on the base *Maeandra*
iploria") *labyrinthiformis*. The costae on the base of *Diploria*
media are similar to those of *Manicina*. Besides the characters
dy mentioned, the calicinal centers in *D. intermedia* are more
nct than in the type-species of *Diploria*. I will therefore desig-
Michelotti's species *Manicina intermedia* (Michellotti). This
ies has narrower (3.5 to 7 mm. wide), shallower (2.5 to 3 mm.
), valleys, and thicker septa than *M. willoughbiensis*, and
e are distinct, thickish paliform lobes on many long septa.
ough the two species are distinct, the genus to which they
ng was coincident in the Oligocene of southern Europe and of the
Indies. D'Achiardi has described two species of this genus as
ophyllia taramellii and *C. flexuosa* from the Eocene of Friuli.

Genus THYSANUS Duncan.

363. *Thysanus* Duncan, Geol. Soc. London Quart. Journ., vol. 19, pp. 430, 439, pl. 15, figs. 3*a*, 3*b*, pl. 16, figs. 6*a*, 6*b*.
363. *Teleiophyllia* Duncan, Geol. Soc. London Quart. Journ., vol. 20, p. 34.
64. *Thysanus* Duncan, Geol. Soc. London Quart. Journ., vol. 21, p. 10.
84. *Thysanus* Duncan, Linn. Soc. London Journ. (Zoology), vol. 18. p. 15.
84. *Teleiophyllia* Duncan, Linn. Soc. London Journ. (Zoology), vol. 18, p. 85.

Type-species.—*Thysanus excentricus* Duncan (Geol. Soc. London
rt. Journ., vol. 19, p. 439, pl. 16, figs. 6*a*, 6*b*).
Duncan included two species in this genus at the time he described
signating neither one as the type. *Thysanus corbicula* occurs
n the paper, but as specimens of it are not accessible for study,

I have selected as the genotype the second species, *Thysanus centricus*, of which I have seen nearly 700 specimens.

THYSANUS aff. T. EXCENTRICUS Duncan.

1863. *Thysanus excentricus* Duncan, Geol. Soc. London Quart. Journ., vol. p. 439, pl. 16, figs. 3*a*, 3*c*.

Apparently the tall variant of *T. excentricus* is represented by c in material from Cuba.

Locality and geologic occurrence.—Cuba, station 3439, in the Cruz marl, first railroad cutting east of La Cruz, near Santia collected by T. W. Vaughan.

THYSANUS HAYESI, new species.

Plate 77, figs. 3, 3*a*, 3*b*.

The type is much damaged, but the three views on plate figures 3, 3*a*, 3*b*, give an idea of its form. The corallum, which about 21 mm. long, 12 mm. tall, and 13 mm. in maximum diame is relatively wide, and is unilateral.

The costae are decidedly prominent, 1 mm. or more tall at the m edge, and are distant, about 2 mm. between the summits of adja costae. Their edges are coarsely and irregularly dentate, the de tions compressed transversely to the septal planes, and seconda spinulose. Toward the base of the corallum the costae become prominent and are obsolete on the base. There are no dist secondary costae.

Nearly all of the septa extend to the columella, they are dis and rather thin; intermediate small septa are rare. Margins dent Faces with sharp ridges and coarse granulations.

Columella trabecular and obscurely lamellate.

Endothecal dissepiments abundant, thin.

Locality and geologic occurrence.—Cuba, station 3461, Gorg Yumuri River, Matanzas, lower Miocene, collected by T. W. Vaug

Type.—No. 324994, U.S.N.M.

This species, which I am naming for Dr. C. W. Hayes, is most ne related to *Thysanus corbicula* Duncan, but differs in its more dist more prominent, and coarser costae.

Family MUSSIDAE Verrill.

Genus SYZYGOPHYLLIA Reuss.

1860. *Syzygophyllia* Reuss, K. K. Akad. Wiss. Wien, Mat., Natur. Cl., Sitzur vol. 39, p. 216, pl. 1, figs. 10–12; pl. 2, fig. 10.

Type-species.—*Syzygophyllia brevis* Reuss.

SYZYGOPHYLLIA HAYESI, new species.

Plate 106, figs. 1, 1*a*, 1*b*.

Corallum compressed-turbinate in form. Greater diameter 75 l esser diameter 59 mm.; height 40 mm.+. The tip of the base

e upper part of the calice of the type are broken. Wall strong, derately thick; with coarsely dentate costae just below the icular edge, lower down covered by thick, finely wrinkled epitheca. The number of septa could not be counted with certainty, there about 200, or approximately 6 cycles. The primaries, secondaries, l tertiaries extend to the columella and are very thick, 1 mm. al and 2 mm. occasional. The quaternaries are shorter and thin-; and the members of the fifth and sixth cycles shorter and thinner n the quaternaries according to cycle. The very thick principal ta with shorter and thinner intermediate septa constitute one of most striking characteristics of the species. The septal margins broken but their character can be inferred from the plan of the ken cross section. There are alternate swollen and thinner areas, wing that the septa are composed of compound trabeculae, and had sely dentate margins. The bases of some of the teeth were prob-y as much as 3 mm. in width, but a more usual width was probably veen 2 and 2.5 mm.

he columella is relatively small, it appears to be entirely composed ne fused inner ends of the septa.

ocality and geologic occurrence.—Nicaragua, Brito formation per Eocene), on or near the Pacific coast; collected by C. W. es, for whom the species is named.

ype.—No. 325009, U.S.N.M.

vo other species of *Syzygophyllia* are known from middle America, *gophyllia gregorii* (Vaughan) and *S. dentata* (Duncan). *S. gre-* was first described from the Bowden marl of Bowden, Jamaica, also occurs in beds of equivalent age in Santo Domingo. *S. ta*, which was described from the Nivajè shale of Santo Domingo, rs stratigraphically above *S. gregorii*, but in deposits paleonto-gally closely related to the Bowden marl. Of the two species *yesi* is more like *S. gregorii*, but its principal septa are thicker ts columella is less developed. Probably the most nearly related es is one collected in the Eocene St. Bartholomew limestone rof. P. T. Cleve, but the specimen that I have seen of this is ood enough for positive identification.

MADREPORARIA FUNGIDA.

Family AGARICIIDAE Verrill.

Genus TROCHOSERIS Milne Edwards and Haime.

49: *Trochoseris* Milne Edwards and Haime, Comptes Rend., vol. 29, p. 72.
05. *Trochoseris* Vaughan, U. S. Nat. Mus. Proc., vol. 28, p. 384.

pe-species.—*Anthophyllum distortum* Michelin.

columella in the type-species is very small, false, and more or apillary.

TROCHOSERIS MEINZERI, new species.

Plate 106, figs. 2, 2*a*, 2*b*.

Corallum trochoid, attached by a basal peduncle. Greater di
eter of calice, 59.5 mm.; lesser diameter, 41 mm.; height, 38.5 m
wall solid, finely and closely costate; costae low, equal or al
nating in size, about 13 in 5 mm. or 26 in 10 mm. Calice, flar
shallow, slightly excavated.

Septa very numerous and crowded, about 16 in 5 mm., 32 i
mm; at the calicular edge, thicker than the width of the ir
septal spaces. Of the septa about every eighth seems to exten
the axial fossa, and 35 were counted around the fossa, but the n
ber of septa probably exceeds 280. The margins are obscu
very finely, dentate, subentire. Synapticulae small, numer
crowded.

Columella very small, 2 mm. in diameter, in a small fossa; a
papillae are recognizable.

Locality and geologic occurrence.—Cuba, station 7522, Mogote P
0.5 mile east of east boundary of United States Naval Reserva
Guantanamo, south side of peak, altitude about 375 feet a. t., colle
by O. E. Meinzer (type).

Panama, station 6587, Tonosi, collected by D. F. MacDonald.

Type.—No. 325228, U.S.N.M.

The only other species of *Trochoseris* described from the Ame
Tertiary formations is *T. catadupensis* Vaughan[1] from the Ec
at Catadupa, Jamaica. This is a much smaller species tha
meinzeri and does not appear closely related.

The specimen obtained by Doctor MacDonald at Tonosi, Pan
is broken and poor, but the identification of it with the C
specimen seems certain.

Genus AGARICIA Lamarck.

1801. *Agaricia* Lamarck, Syst. Anim. sans Vert., p. 373.
1905. *Agaricia* Vaughan, Science, n. s., vol. 21, p. 984.
1917. *Agaricia* Vaughan, Carnegie Inst. Washington Pub. 213, p. 140.

Type-species.—*Madrepora undata* Ellis and Solander.

AGARICIA AGARICITES (Linnaeus).

1758. *Madrepora agaricites* Linnaeus, Syst. Nat., ed. 10, p. 795.
1901. *Agaricia agaricites* Vaughan, Geol. Reichs. Mus. Leiden Samml.,
vol. 2, p. 64.
1902. *Agaricia agaricites* Verrill, Conn. Acad. Arts and Sci. Trans., vol.
146, pl. 26, figs. 2, 3; pl. 27, figs. 1, 2, 2*a*, 3, 3*a*, 5, 6, 6*a*, 7, 7*a*.
1915. *Agaricia agaricites* Vaughan, Washington Acad. Sci. Journ., vol. 5,
1916. *Agaricia agaricites* Vaughan, Carnegie Inst. Washington Yearbook
p. 228.

Locality and geologic occurrence.—Canal Zone, station 6039,
tocene, Mount Hope, collected by D. F. MacDonald, abun

[1] Mus. Comp. Zool. Bull., vol. 34, p. 242, pl. 39, figs. 5, 6, 1899.

is species in its typical form is generally present on the living st Indian and Floridian reefs, and is usual in the Pleistocene fs of the same region.

AGARICIA AGARICITES var. PURPUREA Le Sueur.

1820. *Agaricia purpurea* Le Sueur, Mus. Hist. nat. Paris Mém., vol. 6, p. 276, pl. 15, figs. 3a, 3*b*, 3c.
1902. *Agaricia purpurea* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 149, pl. 27, figs. 4, 4*a*, 4*b*.
1902. *Agaricia agaricites* var. *gibbosa* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 148, pl. 27, figs. 1, 1*a*.
1912. *Agaricia crassa* Vaughan, Carnegie Inst. Washington Yearbook, No. 10, p. 153.
1912. *Agaricia fragilis* var. Vaughan, Carnegie Inst. Washington Yearbook No. 10, pp. 153–154.
1915. *Agaricia purpurea* Vaughan, Washington Acad. Sci. Journ., vol. 5, p. 596.
1915. *Agaricia purpurea* Vaughan, Carnegie Inst. Washington Yearbook, No. 14, p. 228.

ocality and geologic occurrence.—Canal Zone, station Nos. 5849 6039 Pleistocene, Mount Hope, collected by D. F. MacDonald, ndant. This variety is widespread on the living reefs in the st Indies and Florida.

garicia agaricites var. *purpurea* is one of the corals on which I le many experiments at Tortugas, Florida. The following is an ount of one experiment: [1]

e result of one experiment with *Agaricia* gave unexpectedly important informa- on the influence of environment on variation. On the piers of the Fort Jefferson a thin, unifacial, subcircular, or reniform *Agaricia*, attached by the center of ower surfaces, is rather abundant. This seems to be a variety of *Agaricia fragilis* a). On the reefs off Loggerhead Key an *Agaricia* of massive form, several inches ameter and of somewhat less height, is abundant. This appears to be the same *garicia crassa* Verrill. One specimen of the thin *Agaricia fragilis* form attached tile in June, 1910, had by June, 1911, assumed the *Agaricia crassa* growth-form. specimen was attached by its entire lower surface and seems to have had its h-form influenced by the wide basal attachment. It is evident that there is one species of *Agaricia* that under different conditions assumes different growth- . In very quiet water it is thin, orbicular, or reniform, with a slight basal hment at its center, while on the reefs it is more strongly attached and has a massive growth-form. But, in the quiet waters, the massive growth-form may oduced by giving the normally thin form a wide base of attachment, or there is tion to contact. On the reefs, when the water is strongly agitated, there is prob- a clinging of the peripheral polyps to the basal support; this causes the basal hment to cover a larger area than in the more quiet waters; then upward growth this wide base would produce the massive form.

AGARICIA AGARICITES var. CRASSA Verrill.

902. *Agaricia crassa* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 145, pl. 30, fig. 6; pl. 34, fig. 2.
915. *Agaricia crassa* Vaughan, Washington Acad. Sci. Journ., vol. 5. p. 596.
916. *Agaricia crassa* Vaughan, Carnegie Inst. Washington Yearbook, No. 14, p. 228.

[1] Carnegie Inst. Washington Yearbook No. 10, pp. 153–154, 1912.

Locality and geologic occurrence.—Limon, Costa Rica, Moin H
"Niveau *a*," collected by H. Pittier, probably Pleistocene.

As has been stated this is in reality only a vegetative growth fo
of *Agaricia agaricites* var. *purpurea*. It is especially abunda
on the reefs off the west side of Andros Island, Bahamas.

AGARICIA AGARICITES var. PUSILLA Verrill.

1902. *Agaricia agaricites* var. *pusilla* Verrill, Conn. Acad. Arts and Sci. Tra
vol. 11, p. 148, pl. 27, figs. 3. 3*a*.

Locality and geologic occurrence.—Canal Zone, station 6039, Pleis
cene, Mount Hope, collected by D. F. MacDonald, moderat
abundant. This variety was originally based on specimens fr
Colon, Panama.

AGARICIA ANGUILLENSIS, new species.

Plate 108, figs. 2, 3, 4.

Corallum rather low, consisting of crispate, divided, and lol
fronds. Height or extension from the center, 44+mm. Thickn
3 to 4 mm; thinner on the edges.

Calices unifacial, subconcentrically arranged, mother calice exc
tric. In the type-specimen, the distance from the mother calice
the edge of the frond is 35 mm., with five rows of calices, the ou
most calice 6 mm. from the margin, making 7 mm. the average
tance between the rows, the distance varies from 5 or 6 to 9 n
*The lower side of the rows is very slightly swollen; the ridges are alm
suppressed.* Transverse diameter of calices 3 to 7 mm. On
upper side the septo-costae are directly continuous without elevat
to the next series. Under side of frond finely striate.

The septa vary in number from 15 to 38, alternately larger
smaller, arranged in three cycles; 6 to 12 septa are decidedly la
and thicker than the others. The septo-costae are solid and coa
alternately larger and smaller. Synapticulae abundant.

Calicular fossa shallow. Columella stout, composed of two
three large papillæ that fuse to form an axial tubercle or an a
lamella.

Localities.—Island of Anguilla, West Indies; collected by P.
Cleve.

Type.—University of Upsala; duplicates in the United St
National Museum (Cat. No. 324971).

One of the striking characters of this species is the slight tumi
of the lower side of the calices; otherwise it closely resembles *A
ricia dominicensis*, the species next to be described.

AGARICIA DOMINICENSIS, new species.

Plate 109, figs. 1, 1*a*.

The type is a fragment of a frond, 27.5 mm. long, 23 mm. wide,
from 1 to 2.5 mm. thick on the lower edge, exclusive of the calic

tuberances. The width of the frond as given is the true width, the specimen is not broken on its lateral edges. Common wall d, naked. Calices are confined to one surface. The outer surface ongitudinally finely costate; 16 costae, alternating in size, were nted within 5 mm. in two areas. The costae are low, triangular rofile, their bases meeting or with an exceedingly fine costal thread ween them. These costal threads are not included in the count ostae within 5 mm. as given above. A row of small granulations g each costal edge.

alices swallow-nest-like, tend to be arranged in concentric rows series; *lower side protuberant about 3 mm.* Distance between ular series 4 to 7 mm. In the same series adjacent calices con- t but with separate centers; isolated calices may form part of same row. Transverse diameter of isolated calices from 2.5 to m.

pta in largest isolated calices 24 in number, 10 of which extend e columella; as a rule alternately longer and shorter, and alter- ly more and less exsert. Septal margins over the edges of the uberant side of the calices steeply arched but not pointed.

pto-costae with very thin edges, as a rule alternately taller and r; 16 within a linear distance of 5 mm. The septo-costae from upper side of a lower calice or calicular series extend as septo- e to the next higher calice or calicular series and continue as septa of the higher calice or series. Synapticulae are highly loped.

lumella a wide, thin, prominent, axial plate.

cality and geologic occurrence.—Santo Domingo, station No. 7778, Gurabo, zone G, collected by Miss C. J. Maury (type), associated *Placocyathus variabilis* Duncan.

ba, station 3461, gorge of Yumuri River, Matanzas, collected by . Vaughan.

pe.—No. 324973, U.S.N.M., presented by Miss C. J. Maury.

aricia dominicensis differs from *A. anguillensis* by the greater lity and prominence of the lower lips of the calices or calicular ; in fact, the lower edge of the calices in *A. dominicensis* is carried rd so that usually it is as high as or higher than the upper side e calicular aperture. It also differs from *A. anguillensis* in its prominent, platelike columella.

e living *Agaricia nobilis* Verrill,[1] found in Florida, Turks Island Indies), and Porto Rico, is near *A. dominicensis*. *A. nobilis* till a more prominent calicular lip, and more prominent and ;ly alternating septa and septo-costae.

. Acad. Arts and Sci. Trans., vol. 11, p. 150, pl. 28, figs. 1, 2, 1902. See also *Agaricia elephantotus* , U. S. Fish Com. Bull. for 1900, vol. 1, p. 310, pl. 17, fig. 1.

The three species, naming them in geologically ascending series *anguillensis*, *A. dominicensis*, and *A. nobilis*, seem to form an evo tionary series, the lower side of the calices becoming progressiv more produced and more prominent, while the alternation in the s of the septa and the septo-costae increases.

Genus PAVONA Lamarck.

1801. *Pavona* LAMARCK, Syst. Anim. sans. Vert., p. 372.
1917. *Pavona* VAUGHAN, Carnegie Inst. Washington Pub. 213, p. 132.

Type-species.—*Pavona cristata* Lamarck = *Madrepora cristata* E and Solander = *Madrepora cactus* Forskål.

PAVONA PANAMENSIS, new species.

Plate 110, figs. 1, 1*a*, 1*b*, 2, 2*a*, 3, 3*a*.

This species is so variable that formal descriptions of the extremes will be presented.

The first specimen to be described (pl. 110, figs. 1, 1*a*, 1*b*) is f station 6016, Empire, Canal Zone.

Corallum massive or forming thick plates, maximum thickne type 37 mm.

Calices in more or less definite series; diameter, about 4 m distance between series as much as 3.5 mm. Intercalicular a arched or flat.

Septa strongly alternating in size; about 10 prominent, tall s reach the columella; between each pair of these is a lower, sm septum, occasionally three small between two larger septa; edge the larger septa steep around the columella fossa.

Septo-costae continuous from calice to calice, strongly alterna or in places subequal in size; synapticulae visible between them

Columella formed by the fusion of the inner ends of the large se in some calices it appears to be a central tubercle.

Dissepiments well developed; 7 within 4 mm.

The next specimen (pl. 110, figs. 2, 2*a*) is from station 6015, al Empire, Canal Zone.[1]

Corallum forming nodular masses or encrusting dead coral or c such objects. The size and form are shown by plate 110, figur 2*a*. Another specimen has an attached base and flat upper sur

Calices irregularly distributed or in short, indistinct series; dian of the apertures usually range between 2 and 3 mm., as the outli plan is subelliptical or oval the two diameters at right angles rarely equal in the same calice; depth about 1.5 mm.; distance s ranges from a mere dividing wall up to 2.5 mm., about 1 mm. u Intercalicular areas flat between fully developed calices.

Septa, number in fully grown calices 24 to 26; of these about or more than half extend to the columella; around the calicular e

[1] Compare the illustrations of this specimen with the figures of D'Achiardi's *Reussastraea gra* Corall. eocen. Friuli, p. 67, pl. 13, figs. 2*a*, 2*b*, 2*c*, 1875. *Reussastraea* is a synonym of *Pavona*.

y are thick and subequal, within the calice there is indefinite alter-
ion in size, and there may be irregular grouping, but usually the
ll septa do not fuse to the sides of the larger. The septal margins
in the calices fall steeply to the bottom of the relatively large
a.

epto-costae continuous from one calice to the next; they are low,
equal, and synapticulae are visible between them.

olumella formed by the fusion of the inner ends of the long septa;
styliform in many calices, and in some it is distinctly compressed.

specimen from station 6016, represented by plate 110, figures
a, is intermediate in its septal and septo-costal characters between
two other specimens above described.

ocalities and geologic occurrence.—Canal Zone, stations 6015 and
6, in the Emperador limestone, quarry, Empire, collected by
W. Vaughan and D. F. MacDonald.

'otypes.—Nos. 325232, 325334, 325335, U.S.N.M.

his species has its nearest relative in the living *P. clivosa*, from
rl Island, Bay of Panama.

Genus LEPTOSERIS Milne Edwards and Haime.

1849. *Leptoseris* Milne Edwards and Haime, Comptes Rend., vol. 29, p. 72.

ype-species.—*Leptoseris fragilis* Milne Edwards and Haime.

LEPTOSERIS PORTORICENSIS, new species.

Plate 107, figs. 2, 2*a*, 2*b*.

orallum forming a rather thick unifacial frond. The type-speci-
is a fragment and does not give a definite idea of the size to
ch the corallum grew. It is 45 mm. long, of the same width,
5.5 mm. thick. The back is without calices; it is naked and finely
ate, about 23 costae to 1 cm. The costae are subequal in size,
rnately larger and smaller, or every fourth may be slightly larger
n those intervening. The costal edges are narrower than the
es and are finely beaded. Intercostal furrows of about the same
h as the costae.

alices not very definitely arranged, occurring in clusters or in
gular transverse series. Considerable areas are without calices.
h calice is surrounded by from 6 to 9 prominent septo-costae,
all as 2 mm., and 1 mm. thick. Between these on the upper
al) side often there are smaller ones. New calices may originate
oudding from the costate area. Diameter of fully developed
es, about 4 mm. The septo-costae in the noncaliculate areas
coarse, prominent, and equal. Number to the centimeter, 10;
ht as much as 1 mm.; thickness of base, as much as 0.7 mm.
es rather acute and beaded. Intercostal furrows usually nar-
r than the costae. Synapticulae present.

Columella absent, or slightly developed and false.

Locality and geologic occurrence.—Porto Rico, station 3191, 4 mil west of Lares, in the Pepino formation, collected by R. T. Hill.

Type.—No. 325231, U.S.N.M.

It is possible that this species may ultimately be referred to t genus *Mycedium*, to which it is very close.

Genus PIRONASTRAEA D'Achiardi.

1875. *Pironastraea* D'Achiardi, Corall. eocen. del Friuli, p. 76, pl. 15, figs. 2*b*, 3*a*, 3*b*, 3*c*, 3*d*.

Type-species.—*Pironastraea discoides* D'Achiardi,from the Eoce at Brazzano, Russitz, Cormons, and Rosazzo, Italy.

The species described below as *Pironastraea anguillensis* is esse tially typical of the genus except that the basal epitheca is inco plete, occurring only as shreds in both the type-specimens fr Anguilla and in a specimen from Porto Rico, collected by Mr. B Hubbard, of the New York Academy of Sciences Porto Rico expe tion. The columella of *P. discoides*, according to D'Achiardi, is single papilla.

The following generic diagnosis is based on the two West Indi species, *P. anguillensis* and *P. antiguensis*, descriptions of which a subsequently given:

Corallum more or less massive or forming thick undulating pla which expand from a subcentral basal attachment. Lower surfa mostly naked, a few epithecal shreds are present, finely costate; co mon wall synapticular in origin, but in places it is almost or qu solid. Upper surface caliculate.

Calices usually form subconcentric series, some are circumscrib In the series calicinal centers either distinct, or indistinct as *Pachyseris*. Separated by rounded collines, of equal slopes on bo the peripheral and proximal sides; no interserial walls.

Septa lamellate, with few or no perforations; apparently some p forations near the columella, where the trabecular fusion is inco plete. Septal margins with obtuse, crowded dentations, which a compressed transversely to the septal planes, and are more co spicuous around the axial fossa, where the calicinal centers are d tinct, or along the bottom of the valley where the calicinal cent are indistinct. Columella false, in places a few papillae may recognized. Septo-costae equal in size, directly confluent across t collines.

Synapticulae greatly developed, small, crowded.

Geologic occurrences.—Oligocene of Anguilla, Antigua, Cuba, a Porto Rico.

There seems to be only one genus of corals with which compariso need to be made. Milne Edwards and Haime[1] proposed *Oroseris*[2]

[1] Polyp. foss. Terr. paléozoïques, p. 130, 1851.

[2] A synonym of *Comoseris* D'Orbigny, according to Gregory, Juras. Cor. Cutch., pp. 154–156, 1900.

enus, designating as the type-species *O. plana* M. Edwards and me, which is a new name for *Agaricia sommeringii* Michelin [1] t Goldfuss), from the middle Oolite of Mecrin and Hannonville use). A part of the description of *O. plana* is as follows: "Quelques ines minces et peu saillantes entre lesquelles on voit souvent sieurs séries de centres calicinaux. Ceux-ci sont bien distincts et profonds."

he multiple series of calices between collines and the very dis- t calicinal centers appear to be valid generic differences. Further- e in the distinct calices of *Pironastraea* the columella is false but rly papillary, whereas in *Oroseris* the columella is rudimentary. re may be additional differences in septal structure not ascertain- from the short description of the type-species of *Oroseris*.

ironastraea differs from *Pachyseris* by its more distinct calicinal ers; but apparently it is the ancestor of the latter genus.

PIRONASTRAEA ANGUILLENSIS, new species.

Plate 111, figs. 1, 1*a*, 1*b*; plate 112, figs. 1, 1*a*.

orallum forming plates as much as nearly 5 cm. thick, and more h 12 cm. across. Width of valleys measured between collines mits from 2.5 to 5.5 mm., about 4 mm. usual; height of collines ve the bottom of the axial furrow or of the columella pit about m. Distance between distinct calicinal centers ranges from 3 mm.

pta numerous, from 38 to 45 in fully developed calices, most of extend to the axis, some grouping in 3's at the calicular ends. a septum 2 mm. long about 10 crowded, knot like dentations. o-costae equal, crowded, 18 were counted within 5 mm.

e columella fossa, where the calicinal centers are distinct, is a l pit, less than 0.5 mm. in diameter.

napticulae abundant, crowded, 7 or more to an interseptal us.

cality and occurrence.—Anguilla, stations 6893, 6894, 6966, rus Bay, T. W. Vaughan collector. A specimen from station 9 was obtained in place between 30 and 50 feet above the base e bluff on the west side of Crocus Bay.

rto Rico, Lares Road, zone C, collected by Mr. Bela Hubbard e New York Academy of Sciences Porto Rico Expedition.

ype.—*No.* 325174, U.S.N.M., pl. 111, figs. 1, 1*a*, 1*b*.

ratype.—No. 325175 U.S.N.M., pl. 112, figs. 1, 1*a*.

[1] Iconograph zoophytol., p. 105, pl. 23, fig. 2, 1843.

PIRONASTRAEA ANTIGUENSIS, new species.

Plate 112, figs. 2, 2*a*; plate 113, figs. 1, 1*a*.

Corallum massive. Type a small specimen, 48 mm. long, 32 m wide, and about 30 mm. thick. Subsequently two larger specime apparently referable to this species, will be described.

Width of calicinal series, measured between colline summits mm. to 7.5 mm. Valleys shallow, about 1.5 mm. deep. Colli with broader bases than in *P. anguillensis*, some colline-profiles more triangular than in the latter species. Distance between c cinal centers in the same series about 4.5 mm.

Septa numerous, about 48 in a calice 6 mm. in diameter, betw 12 and 14 extend to the axis, other septa shorter, irregularly fu in pairs or in groups of three. Around the calicular edges all se are subequal; their thickness about the same as or slightly less th the width of the interseptal loculi. The septal margins with blunti crowded dentations, 20 were counted in a length of 3.4 mm.

Septo-costae subequal, crowded, each of three counts in differ places gave 22 to 5 mm. of linear distance. Synapticulae numerc crowded, 9 were counted in a distance of 2.5 mm. along the cou of a septum.

Columella false, papillary, not sunken in a definite pit.

Locality and occurrence.—Antigua. Type (pl. 112, figs. 2, 2*a*) fr the Antigua formation, station 6854, Rifle Butts, T. W. Vaugh collector; and station 6880, west side of Otto's estate, T. W. Vaugh collector. The last-mentioned specimen is silicified and broken, it as it presents the general aspect of the type of *P. antiguensis*, and fr from 18 to 22 septo-costae to 5 mm., the specific identity of the t specimens appears certain.

Cuba, station 7514, about 5 miles nearly due east of monum H 4 on the east boundary of the United States Naval Reservat Guantanamo, altitude about 400 feet a. t., collected by O. E. M zer. The latter specimen is represented by plate 113, figures 1, 1

Type.—No. 325177, U.S.N.M.

Paratype.—No. 325179, U.S.N.M.

P. antiguensis differs from *P. anguillensis* in its more mas growth form, wider valleys, lower collines, more numerous se costae, and the absence of a columella pit. The calicinal center in the specimen from station 7514, near Guantanamo, Cuba, are usu joined by an axial septum extending from one to the next cen producing the appearance of an axial lamella. The lamella, h ever, is not a columella, for the calicinal centers are usually recog able, and when they are distinct there are a few papillae in columellar area. It appears that the well-developed axial lamel is one of the specific characters, but the suite of specimens, three in all, is too small to be sure of this.

Genus SIDERASTREA de Blainville.

1801. *Astrea* (part) LAMARCK. Anim. sans Vert., p. 371 (not *Astraea* Bolten, Mus. Boltenianum, p. 79, 1798).
1815. *Astraea* OKEN, Lehrb. der Naturg., Th. 3, Abth. 1, p. 75.
1830. *Siderastrea* DE BLAINVILLE, Dict. Sci. nat., vol. 60, p. 335.
1846. *Siderina* DANA, U. S. Expl. Exp. Zoophytes, p. 218.
1848. *Siderastrea* MILNE EDWARDS and HAIME, Comptes Rend., vol. 27, p. 495.
1857. *Astraea* MILNE EDWARDS and HAIME, Hist. nat. Corall., vol. 2, p. 505.
1861. *Astrea* DE FROMENTEL, Introd. à l'Étude des Polyp. foss., p. 235.
1886. *Siderastraea* QUELCH, Challenger Exp. Reef Corals, p. 133.
1890. *Siderastraea* VERRILL, In Dana's Corals and Coral Islands, ed. 3, p. 424.
1895. *Astraea* GREGORY, Geol. Soc. Lond. Quart. Journ., vol. 51, p. 278.
1900. *Siderastrea* VAUGHN, U. S. Geol. Survey Mon. 39, p. 154.
1907. *Siderastrea* VAUGHAN, U. S. Nat. Mus. Bull. 59, p. 136.

Type-species.—*Madrepora radians* Pallas.

In the last publication cited in the synonymy given above I said discussing the genus *Pavona:* Two of these species [of *Pavona*], *P. vus* Dana and *Siderastrea maldivensis* Gardiner, have been referred the genus *Siderastrea*, type species *Madrepora radians* Pallas; and y superficially resemble that genus. Upon closer scrutiny an litional resemblance is found in the distinct, continuous corallite lls, but there are important differences. The septal margins of species [of *Pavona*] discussed in the foregoing remarks are entire microscopically dentate, and the septal lamellae are absolutely d. In the 5 or 6 species, specimens of which I have studied, there persistently a lamellate columella or a compressed styliform colu-lla. *The septal margins of Siderastrea are pronouncedly dentate,* dentations rounded, one dentation corresponding to each septal becula. *The younger septa are distinctly perforate, the perforations being confined to the inner edges.*"

t would seem that this clear statement of certain characters of *erastrea* should have stopped the erroneous reference to it of such cies of *Pavona* as *P. clavus* Dana and *P. maldivensis* (Gardiner) ughan,[1] yet Felix in his Die fossilen Anthozoen aus der Umgegend Trinil (Java)[2] persists in the erroneous reference to it of species nging to another genus or other genera. He places in *Siderastraea* sspelling the generic name) *S. blanckenhorni*, new species, which n his figures[3] and his descripition,[4] is certainly not *Siderastrea*, *olumnaris*, new species, *S. maldivensis* Gardiner, and *S. micrommata*, new species, no one of which belongs to *Siderastrea*.

his is not the only misuse or misunderstanding of the generic nes of corals by Felix in the paper cited. In others of his publi-

[1] For a discussion of the known living species of *Pavona*, see Vaughan, Some shoal-water corals from Fiji Island (Australia), Cocos-Keeling Islands, and Fanning Island, Carnegie Inst. Washington Pub. 213, p. 132–139, 1918. Notes on *P. maldivensis* (Gardiner) Vaughan are given on page 138, and it is illustrated by plate 56, figs. 3, 3*a*, 3*b*.
[2] Palaeontographica, vol. 60, pp. 311–365, pls. 24–27, 1913.
[3] Idem, plate 27, figs. 6, 6*a*.
[4] Idem, p. 333.

cations, he does not follow the accepted canons of systematic zoolog an instance being in his application[1] of *Parastraea*,[2] originally nam by Milne Edwards and Haime, to a species, *Parastraea grandiflo* erroneously referred to *Parastraea* by Reuss. There are in t United States National Museum specimens of this species receiv from Professor Felix; they belong to a genus of fungid corals relat to *Diploastrea* Matthai, but I am not decided as to their gene identification. However, they most emphatically do not belong *Parastrea*. Other instances of similar errors in Felix's work mig be mentioned.

In order to present properly the systematic affinities of the spec of *Siderastrea* that need to be considered in this paper, it is desira to discuss all Oligocene and later species known from the W Indies, Central America, and the southeastern United States. *stellata* Verrill from Brazil is also included.

Siderastrea is represented in the living Caribbean and Florid fauna by *S. radians* (Pallas) and *S. siderea* (Ellis and Soland The fossil species hitherto described from the West Indies are follows:

S. conferta (Duncan)[3] (as *Isastraea*) from Antigua.

S. crenulata var. *antillarum* Duncan [4] from Santo Domingo.

S. grandis Duncan [5] (syn. of *S. siderea*) from Jamaica.

S. pariana (Duncan)[6] (as *Astraea*) from St. Croix, Trinidad.

S. confusa (Duncan)[7] (as *Isastraea*) from St. Croix, Trinidad.

S. hexagonalis Vaughan[8] from the Eocene Clayton limeste Prairie Creek, Alabama.

S. clarki Nomland [9] from the Oligocene *Agasoma gravidum* zo Contra Costa County, California.

S. mendenhalli Vaughan,[10] Pliocene, Carrizo Creek, California.

S. californica Vaughan,[11] Pliocene, Carrizo Creek, California.

Neither the Californian species nor the Eocene *S. hexagonalis* wil specially considered here.

Duncan's *S. crenulata* var. *antillarum* is probably a synonym *S. siderea;* his *S. grandis* is certainly a synonym of *S. siderea*. A

[1] Palaeontographica, vol. 49, p. 181, 1903.

[2] *Parastrea* Milne Edwards and Haime, Comptes. Rend., vol. 27, p. 495, 1848; examples *Astrea ro* and *A. ananas* Lamarck. Placed in the synonymy of *Favia* by Milne and Haime, Hist. nat. Corall 2, p. 426.

[3] Geol. Soc. London Quart. Journ., vol. 19, p. 422, pl. 14, fig. 2, 1863.

[4] Idem, p. 435.

[5] Idem, p. 441, pl. 16, figs. 5*a*, 5*b*.

[6] Geol. Soc. London Quart. Journ., vol. 24, p. 14, 1867

[7] Idem, p. 14, pl. 2, fig. 6.

[8] U. S. Geol. Survey Mon. 39, p. 155, pl. 18, figs. 1–4, 1900.

[9] Univ. Calif. Pub., Bull. Dept. Geology, vol. 9, p. 65, pl. 5, figs. 3, 4, 1916.

[10] U. S. Geol. Survey Prof. Pap. 98–T, p. 374, pl. 101, figs. 3, 3*a*, 4, and var. *minor*, Idem, p. 375, p fig. 1, 1917.

[11] Idem, p. 375, pl. 102, figs. 2, 2*a*, 3, 4.

nal specimens of *S. pariana* and *S. confusa* from St. Croix, Trinidad, needed before those species can be adequately characterized, but original descriptions of them are included. Therefore, the following old names are adopted in the discussion here given:

. radians (Pallas), living.

. siderea (Ellis and Solander), living; fossil in the Miocene Bowden l of Jamaica and in deposits of similar age in Santo Domingo and a.

. stellata Verrill, living.

. conferta (Duncan), fossil.

. pariana (Duncan), fossil.

. confusa (Duncan), fossil.

am describing as new five species and one variety as follows:

. pourtalesi, upper Oligocene or lower Miocene of Santo Domingo.

. pliocenica, Pliocene Caloosahatchee marl, Florida.

. hillboroensis, lower Miocene Alum Bluff formation, Florida; ocene Chattahoochee formation.

. silecensis, Oligocene Tampa formation, Florida, and Chattahee formation, Florida and Georgia; lower Miocene, Alum Bluff nation, Florida.

. dalli, Pliocene Caloosahatchee marl, Florida.

hese species may be divided into five groups on the basis of the ber of septa. The first group has only three cycles of septa and ains one species; the second group has the fourth cycle of septa mplete; the third normally has four complete cycles and occaally a few quinaries; the fourth has uniformly a few quinaries in developed calices; the fifth has from 12 to 43 quinary septa in developed calices. The following synopsis of some striking acters may aid in recognizing the different species:

SYNOPSIS OF CHARACTERS OF SPECIES OF SIDERASTREA.

3 cycles of septa..... 1. *S. pariana* (Duncan).
h cycle of septa incomplete.
olumellar fossa a pronounced pit.
Calices rarely 4 mm. in diameter.
Columella composed of from 1 to 3 fused papillæ. 2. *S. radians* (Pallas).
Calices deformed, lesser diameter 2 to 3 mm., length as much as 6.5 mm., or more.
Columella finely papillary..... 3. *S. stellata* Verrill.
olumellar fossa only moderately deep.
Calices 2.5 to 5 mm. in diameter.
Columella false..... 4. *S. confusa* (Duncan).
olumellar fossa shallow, calices shallow and open.
Wall delicate, interseptal loculi relatively open. 5. *S. pourtalesi*, new species.
Wall stout, interseptal loculi narrow, largely closed by granulations and syapticulae (fourth cycle complete in some large calices).
6. *S. pliocenica*, new species.

Fourth cycle of septa normally complete, a few quinaries in large calices.

Columellar fossa not very deep; lesser diameter of calices from 4 to 6 mm.; tert septa fuse to secondary distinctly back from the columella; about 4 septal t to 1 mm. (fourth cycle of septa incomplete in some calices).

7. *S. hillsboroensis*, new spec

Columellar fossa deep, rather narrow at the bottom; calices 3 to 5 mm. in di eter; tertiary septa normally fuse to secondaries distinctly back from columella; 6 to 8 septal teeth to 1 mm.... 8.[1] *S. siderea* (Ellis and Solanc

Four complete cycles and normally some quinaries septa.

Columellar fossa rather deep and wide bottomed; calices 5 to 7, even 8 mm diameter; tertiary septa fuse to secondaries near or at the columella; septa septal teeth less numerous than in No. 11; septal teeth not transversely c pressed and frosted as in No. 10..... 9. *S. silicensis*, new spe

Columellar fossa shallow, calices widely open; calices 5 to 6.5, even 8, mm. in r imum diameter; tertiary septa fuse to secondaries near the columella; se teeth numerous, crowded, transversely compressed, finely frosted.

10. *S. dalli*, new spe

Four complete cycles of septa and many quinaries.

Columellar fossa shallow or rather deep and narrow; calices from 4.25 to 6, u 8.5 mm. in maximum diameter; septa numerous, up to 91 in large calices, crowded; septal teeth small, crowded..... 11. *S. conferta* (Dunc

The foregoing is intended to aid in the preliminary placing c species with reference to the other members of the genus, and is a complete summary of characters. The details of the mural char ters, the relative thickness and crowding or remoteness of septa, the septal trabeculae, the dentation of the septal margins, distribution and size of the synapticulae, and the details of columella, all need to be considered. For these additional det the descriptions and the rather elaborate illustrations must be c sulted.

1. SIDERASTREA PARIANA (Duncan).

1867. *Astraea pariana* DUNCAN, Geol. Soc. London Quart. Journ., vol pp. 14, 24.

Original description.—"The corallum is massive and rather and its upper surface is flat. The corallites are slender, tall, crowc and equal. The calices are small, and the fossa is rather deep. columella presents one rounded process. The septa are in six s tems and there are three cycles; they are alternately large and sm and the smallest usually unite to the large septa; they are fair dentate. The laminae present on their sides sets of granules horizontal but wavy lines. The endotheca is rare. The diam of the calices is one-twelfth inch [2 mm.]."

Locality.—St. Croix, Trinidad.

[1] *S. siderea* var. *dominicensis*, new variety, is like *S. siderea* except that it has larger calices and spondingly a number of quinary septa.

2. SIDERASTREA RADIANS (Pallas).

Plate 114, fig. 1.

1766. *Madrepora radians* PALLAS, Elench. Zooph., p. 322.
1767. *Madrepora astroites* LINNAEUS, Syst. Nat., ed. 12, p. 1276 (not Pallas, 1766).
1786. *Madrepora galaxea* ELLIS and SOLANDER, Nat. Hist. Zooph., p. 168, pl. 48, fig. 7.
1801. *Astrea galaxea* LAMARCK, Syst. Anim. s. Vert., p. 371.
1815. *Astraea radians* seu *astroites* OKEN, Lehrb. Naturgesch., Th. 3, Abth 1, p. 65.
1830. *Astrea* (*Siderastrea*) *galaxea* DE BLAINVILLE, Dict. Sci. nat., vol. 60, p. 335.
1834. *Astraea astroites* EHRENBERG, Cor. Roth. Meer., p. 95 (of separate). (Not *Explanaria galaxea* Ehrenberg=*Cyphastraea savignyi* Milne Edwards and Haime.)
1846. *Siderina galaxea* DANA, U. S. Expl. Exped. Zooph., p. 218, pl. 10, figs. 12, 12b, 12c (*not* figs. 12*a*, 12*d*).
1880. *Siderastraea galaxea* POURTALÈS, Mus. Comp. Zool. Mem., vol. 7, pt. 1, pl. 11, figs. 14–31; pl. 15, figs. 1–12.
1895. *Astræa radians* GREGORY, Geol. Soc. Lond. Quart. Journ., vol. 51, p. 277.
1901. *Siderastrea radians* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 61.
1901. *Siderastrea radians* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 309, pl. 15, pl. 16, fig. 2.
1902. *Siderastraea radians* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 153, pl. 30, fig. 1.
1904. *Siderastrea radians* DUERDEN, Carnegie Inst. Washington Pub. No. 20, pp. 1–130, 11 plates.
1915. *Siderastrea radians* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 597.
1916. *Siderastrea radians* VAUGHAN, Nat. Acad. Sci. Proc., vol. 2, pp. 95 *et passim*.
1916. *Siderastrea radians* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, p. 228.

This is one of the best known species of Antillean corals. Its most important characters may be summarized as follows: Calices more or less deformed or subhexagonal; diameter from 2 to 4 mm.; septa in 3 complete cycles; fourth cycle normally incomplete. Outer part of septal margins flattened above, inner part falls steeply, almost perpendicularly, to the bottom of the columellar fossa; septal dentations relatively coarse, 12 to 14 on long septa. Columella finally composed of two or three solidly fused papillae. All of these characters are shown on plate 35, figure 1.

Locality and geologic occurrence.—Canal Zone, stations 5850 and 5859, Pleistocene, Mount Hope, collected by D. F. MacDonald. Common on the living and Pleistocene reefs and reef flats of eastern Central America, the West Indies, and Florida; on the living reefs and reef flats of the Bermudas.

3. SIDERASTREA STELLATA Verrill.

Plate 115, figs. 2, 2*a*, 2*b*.

1868. *Siderastraea stellata* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 1, p. 3
1901. *Siderastrea stellata* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., ser.
vol. 2, p. 62.
1902. *Siderastraea stellata* VERRILL, Conn. Acad. Arts and Sci. Trans., vol.
p. 155, pl. 30, figs. 4, 5.

This species resembles *S. radians* in usually having the four
cycle of septa incomplete, in the flattened outer margins and ve
steep inner margins of the septa, and a deep columellar fossa.
differs, as a comparison of the figures shows, by having deeper calic
which may be meandriform, by its more coarsely dentate septa, a
by its much less developed, finely papillate columella. It is a ve
distinct species and is not a synonym of *S. siderea*, as Gregory su
posed.[1] The specimen figured (pl. 115, figs. 2, 2*a*, 2*b*) is No. 368
U.S.N.M.

Locality and geologic occurrence.—"It is widely distributed on t
coast of Brazil; Bahia, Abrolhos reefs, etc.;" living.[2]

4. SIDERASTREA CONFUSA (Duncan).

1867. *Isastraea confusa* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24,
14, 24, pl. 2, fig. 6.

Original description.—"The corallum is short, and covers mu
space. The corallites are very irregular in size, and the calices al
The fossa is moderately deep, and presents a false columella. T
septa are thick, and unite laterally in sets of three, four, or six. T
free margin is faintly dentate. The largest calices have four cy
of septa in six systems; but usually only three cycles are found
smaller calices. The diameter of the calices is from one-tenth
four-tenths inch 2.5 to 10 mm."

Locality.—St. Croix, Trinidad.

5. SIDERASTREA POURTALESI, new species.

Plate 115, figs. 1, 1*a*.

1875. *Siderastraea galaxea* POURTALÈS, Geol. Mag., new ser., dec. 2, vol. 2, p.

The specimen identified by Pourtalès as *Siderastrea galaxea* (E
and Solander) = *Siderastrea radians* (Pallas), the older name, is
that species, but as it is closely related the following is a compara
diagnosis.

In growth, form, size of calices, and septal arrangement, *Sideras*
pourtalesi is similar to *S. radians*, but the wall is very thin, e
interrupted, zigzagging between the thick outer ends of the wed
shaped septa. The interseptal spaces are relatively wide and

[1] Geol. Soc. London Quart. Journ., vol. 51, p. 279, 1895.
[2] Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 155, 1902.

nspicuously open. Synapticulae are present, but they are rather arce, and are delicate. The delicate wall and synapticulae and the lative openness of the interseptal loculi constitute striking differ- ces from the appearance presented by *S. radians*.

Locality.—Santo Domingo, collected by W. M. Gabb.

Type.—Museum of Comparative Zoology.

6. SIDERASTREA PLIOCENICA, new species.

Plate 118, figs. 2, 2*a*, 2*b*, 3.

Twelve specimens, all of them excellent, serve as the basis of the lowing specific diagnosis. One is designated as the type in the lection.

The corallum usually forms a rather small rounded head; but a are elongate, and one is flattish, sublamellate. The heads attain iameter of between 45 and 50 mm. About a third of the speci- ns show signs of having been attached or have not calices uni- mly distributed over the whole outer surface of the corallum.

The corallites are rather large, and are rather uniformly hex- nal or pentagonal; usual diameter is 4.5 to 5 mm.; intercorallite l distinct and zigzag in plan. The calices are shallow or super- al.

epta thick, usually in almost four complete cycles, the fourth e is as a rule absent in one or two systems. Septal margins tate, each dentation rounded, corresponding to the upper termi- on of a septal trabecula, the number of dentations on a septum he first cycle varies from 8 or 9 to 13. The length of such a um is almost 2.5 mm. Septal grouping is as usual in the genus, members of the first cycle are continued directly to the colu- ar space and do not form parts of septal groups; the members he second cycle, also, are continued directly to the columellar e, but each member of this cycle is the middle of a septal group, members of the third cycle bend toward it, and the members e fourth bend toward the included member of the third. Along course of each trabecula is a regular row of granulations, which compressed in a plane transverse to the longitudinal course of trabecula. Septal perforations are frequent near the inner ins of the septa, usually occurring in the intertrabecular spaces, in places a large perforation interrupts a trabecular course. perforations become rarer as the wall is approached. Com- ly imperforate septa are very rare or do not exist at all.

th synapticulate and dissepimental endotheca is present. In s as many as four or five vertical rows of synapticulae can be st guished. Very thin dissepiments are abundant. The wall is d by synapticulae that are so elongated in a vertical row that

they fuse and produce a continuous wall with only an occasi
perforation.

The columella is papillary, about two papillae being larger t
the others. In worn specimens it is very prominent, appearing c
pressed styliform.

Locality and geologic occurrence.—Florida, Caloosahatchee Ri
collected by W. H. Dall; Shell Creek, Florida, collected by Do
Griffith; Pliocene.

Type.—No. 325184, U.S.N.M.

Paratype.—No. 325185, U.S.N.M.

The most striking differences between *S. pliocenica* and *S. radi*
to which it probably has the greatest affinity, are its larger
much shallower calices. *S. californica* Vaughan from the Pliocen
Carizo Creek, California, is a nearly related species.

7. SIDERASTREA HILLSBOROENSIS, new species.

Plate 117, fig. 2.

Description of the type.—Corallum massive, composed of l
prismatic corallites. No entire corallum is available for descrip
but the height may certainly exceed 10 cm.

Diameter of a large corallite, 5.5 mm.; of a smaller one, 4
The two measurements indicate the range in diameter.

Septa normally in 4 cycles, the fourth cycle complete or al
complete, arranged as follows: The six primaries extend direct
the columella and are free from fusion with other septa; the seco
ries also extend to the columella, near which the tertiaries fus
sides of the included secondaries; the quaternaries fuse to the
of the included tertiary system about halfway between the wall
the columella. The fourth cycle is incomplete in a few quarter
tems of some calices. The primaries and secondaries are of a
equal thickness; the tertiaries slightly thinner, and quatern
still thinner. The number of dentations on the septal margins
estimated from the number of septal trabeculae, as the septal ma
are not preserved; it is 9 or 10.

Synapticulae well developed; in each interseptal loculus; thr
four are usually conspicuous between the wall and halfway
it to the columella. Although the upper septal margins are not
served, it seems probable that there is a flattened area bet
adjacent calicular fossae in perfect specimens.

Columella false, but strongly developed by the axial fusion
inner ends of the primary and secondary septa.

Localities and geologic occurrence.—Station No. 4890, Tampa
yard, 5 miles northeast of Tampa, Florida, in the Alum Bluff f
tion, G. C. Matson collector, the type; in the Alum Bluff form
at station No. 3836, near Alachua, Florida, T. W. Vaughan coll

d at White Springs, Florida, T. W. Vaughan and L. W. Stephen-
n, collectors. Station 7076, in the Chattahoochee formation, 12
les below Bainbridge, Georgia, on the east bank of Flint River,
llected by C. W. Cooke and W. C. Mansfield.

Type.—No. 325183, U.S.N.M.

Paratype.—No. 325155, U.S.N.M., the specimen described below.

The diagnosis of *S. hillsboroensis* was written and the figures made illustrate it before an interesting specimen from 12 miles below inbridge came to my notice. This specimen, which is a subcy-ndrical segment of a more or less columnar corallum, has a maxi-um horizontal diameter of 160 mm., and a vertical thickness of 75 n. The entire corallum was rather large. The septal margins er considerable areas are somewhat elevated around the calicular sae and the rims are separated by depressed interspaces that in ces are as much as 2 mm. across. Adjacent corallites, however, separated by simple common-walls. The number of septa in y developed calices ranges from a few less than to about four mplete cycles, grouped as in the types of the species. The septal tations are strikingly large. The following table gives the dimen-ns of several corallites, the number of septa, the number of septal th within 1 mm., and the character of the columella:

Dimensions of corallites, etc., in Siderastrea hillsboroensis.

Corallite No.	Diameter corallites.	Number of septa.	Septal teeth.	Columella.
	5 by 7.5 mm	50		
	4.5 by 6.6 mm			
	5.5 by 6 mm			
	6 by 6.75 mm	48		Weak.
	5.25 by 7 mm	50		Do.
	4.5 by 6.5 mm	48		Do.
			4 in 1 mm	
			do	
			5 in 1.5 mm	
			6 in 1.5 mm	
			do	

. hillsboroensis has some corallites of nearly the same size as those of *. ilecensis*, but they average smaller; it has thicker and relatively er septa which fuse into groups farther from the columella; and h septal teeth are distinctly coarser.

8. SIDERASTREA SIDEREA (Ellis and Solander).

Plate 114, figs. 2, 3; plate 122, figs. 1, 2, 2*a*, 2*b*, 3, 3*a*.

786. *Madrepora siderea* Ellis and Solander, Nat. Hist. Zooph., p. 168, pl. 49, fig. 2.

816. *Astrea siderea* Lamarck, Hist. nat. Anim. s. Vert., vol. 2, p. 267.

830. *Astrea* (*Siderastrea*) *siderea* De Blainville, Dict. Sci. nat., vol. 60, p. 335.

834. *Astraea tricophylla* Ehrenberg, Cor. Roth. Meer., p. 95 (of separate) (*fide* Milne Edwards and Haime).

1846. *Pavonia siderea* Dana, U. S. Expl. Exped. Zooph., p. 331.
1850. *Siderastrea siderea* Milne Edwards and Haime, Ann. Sci. nat., ser. Zool., vol. 12, p. 141.
1857. *Astraea siderea* Milne Edwards and Haime, Hist. nat. Corall., vol. p. 509, pl. D7, fig. 2.
1863. *Siderastraea grandis* Duncan, Geol. Soc. London Quart. Journ., vol. p. 441, pl. 16, figs. 5*a*, 5*b*.
1871. *Siderastraea siderea* Pourtalés, Mus. Comp. Zool. Ill. Cat. No. 4, p.
1895. *Astraea siderea* Gregory, Geol. Soc. London Quart. Journ., vol. 51, p. 2
1901. *Siderastrea siderea* Vaughan, Geolog. Reichs-Mus. Leiden Samml., ser vol. 2, p. 62.
1901. *Siderastrea siderea* Vaughan, U. S. Fish. Com. Bull. for 1900, vol. 2, p. pl. 14, figs. 1, 2; pl. 16, fig. 1.
1902. *Siderastraea siderea* Verrill, Conn. Acad. Arts and Sci. Trans., vol. p. 151, pl. 30, figs. 2, 3.
1903. *Siderastraea siderea* Duerden, Nat. Acad. Sci. Mem., vol. 8, p. 588, 22–24, figs. 150–160.
1915. *Siderastrea siderea* Vaughan, Washington Acad. Sci. Journ., vol. 5, p.
1916. *Siderastrea siderea* Vaughan, Carnegie Inst. Washington Yearbook No. p. 228.

This species forms much larger masses than *S. radians*, the ot abundant living species of *Siderastrea* in the West Indies and Flori and is a common exposed-reef coral. The calices average larger th in *S. radians*, usually 4 to 5 mm. in diameter, occasionally smal 3 to 3.5 mm. in diameter. The intercorallite walls are more ac and the septal margins are more sloping; but, as is shown on pl 114, figure 3, on some areas the corallite wall may occur in a sli depression (pl. 114, fig. 2). The septa are normally in four compl cycles, arranged as in figure 3, on plate 114. The tertiary septa f to the secondaries, and the quaternaries to the tertiaries nearer wall than in *S. silecensis*, the next species to be described. septal margins are more finely dentate than in *S. radians*, and usu the columella is distinctly, finely papillate.

The foregoing notes are on shallow-water specimens, and apply specimens ranging in locality from Barbados to the Bahamas in West Indies, from Central America, and from Florida. About half mile south of Loggerhead buoy, Tortugas, in water betwee and 9 fathoms, I dredged three specimens of *S. siderea* that show v interesting variation. The size and shape of the calices, the chara of the wall, the number of septa, and the axial fossae are as u in the species; but the septa are thicker, the septal pectinations more conspicuous, and the columellar papillae are solidly fuse there is a single, stout, compressed axial tubercle. A group of cal is shown on plate 122, figure 1. These specimens agree in all es tial particulars with a specimen from the Bowden marl of Jamaic description of which follows:

Description of specimen from Bowden, Jamaica (pl. 122, figs. 3, 3*a*
Corallum with a rounded upper surface and a flattish base: epi

ate around the edge. Transverse diameters, 36 by 38 mm.; height 6 mm.

Calices irregularly polygonal, excavated on top of the corallum, but shallow near its edges. Length of largest calices, 5.5 mm.; width of largest calices, 3.5 to 4 mm.; 4 to 4.5 mm. about the usual diameter; depth between 2 and 2.25 mm. The area between adjacent calicular depressions is relatively acute, the wall usually traceable along the summit as a slightly raised zigzag or straight line.

Septa thicker than the width of the interseptal loculi; four complete cycles and in the larger calices some quinaries; primaries and secondaries extend to the columella, subequal, or the primaries slightly larger; tertiaries fuse to the included secondary about two-thirds the distance from the wall to the center of the calice or very near the columella; quaternaries fuse to the included tertiary about one-third or one-half the distance from the wall to the calicular center; quinaries where present fuse to the included quaternary.

Septal margins slope gently from the wall to about half the distance toward the calicular center and then incline steeply to the outer edge of the columella. The dentations are small, crowded, and bluntish or rather acute, more pointed near the columella, compressed in planes transverse to the septal planes; 15 were counted on a septum 2.5 mm. long; in other words, 6 within 1 mm.

Synapticulae crowded near the wall, 3 within 1 mm. measured down the septal slope from the wall edge.

Columella small, false, papillary; a central, styliform papilla noticeable in many calices.

Description of a specimen collected by Miss C. J. Maury in Santo Domingo, Rio Cana, zone H (pl. 122, figs. 2, 2*a*, 2*b*).—Corallum a small mass, with a flattish base and a rounded upper surface. Diameter, 32 by 28 mm.; height, 15 mm.

Calices shallow, polygonal, usually one diameter longer than the other, separated by narrow, straight, or zigzag walls. Diameter of largest calice, 6 mm.; about 4 mm. a usual measure of the diameter. In the largest calice (6 mm. in diameter) there are 52 septa, which, according to the usual practice of assigning septa to cycles, would represent 4 complete cycles and 4 quinary septa. Fifteen septa, 6 primaries, 6 secondaries, and 3 tertiaries, extend to the columella, and 2 other tertiaries fuse to the included secondary almost at the periphery of the columella. Where quinary septa are present it is difficult to distinguish between primaries and secondaries, and between the elongate tertiaries and the secondaries. In a calice 4 mm. in diameter the septal arrangement is more definite; there are 40 septa, the quaternaries not being developed in one quarter system. The tertiaries fuse to the secondaries either rather near

the columella and the quaternaries to the tertiaries about halfwa
between the wall and the columella, or somewhat nearer the columell
At the wall the thickness of the septa and the width of the intersept
loculi are nearly the same, but farther within the calice the sept
are thinner and the loculi are wider.

Next the wall the septal margins are usually flattened from abov
producing a flat area ranging from about 0.5 to about 1 mm. wide, i
inner edge marked by a ring of synapticulae, and the wall forms
more or less median slightly raised ridge. From this area the margi
slope slightly to the bottom of the calicular fossa. The peripher
flat zone is not present in all calices; in many there is a gradual slo
or a gently convex curve from the wall to the bottom of the calic
On the septal margins are fine, crowded, bluntish dentations, whi
in many instances are compressed transversely to the septal plan
About 16 were counted on a septum 2 mm. long; 12 were count
on another septum 1.5 mm. long. The number, therefore, is betwe
8 and 9 for a distance of 1 mm. The septal faces are closely bes
with blunt granulations. Synapticulae well developed near the wa

Columella rather small, with a delicately papillate upper surfa
in the best-preserved calices.

This Santo Domingan specimen has greatly puzzled me, perha
partly because it is immature. The calices are shallow, not having
distinct axial fossa, as in typical *S. siderea*, and the septal dentatio
are more numerous than is usual in *S. siderea*. As the calices of t
Bowden specimen are excavated on the top of the corallum a
superficial near the lower edge, the shallowness of the calices of t
Santo Domingan specimen does not seem a sufficient basis for referri
it to a different species. Although the septal dentations are finer th
the average in *S. siderea*, they are not finer than the dentations on t
outer prolongations on some of the septa of the specimens represent
by plate 35, figures 2, 3, in which there are 8 or 9 fine teeth withi
mm. outside the calicular fossa. For these reasons it seems to
that the Santo Domingan fossil should be referred to *S. sider*
and I believe that the coral designated as *Siderastraea crenul*
var. *antillarum*[1] by Duncan should also be referred to *S. sider*
Duncan says that his variety *antillarum* is near *S. siderea*. I
amined Duncan's type in the collection of the Geological Soci
of London. It is a flattened mass, rounded above. Calices irre
larly polygonal or hexagonal, separated by sharp walls; diame
4 to 5 mm. Septa in four complete cycles, margins beaded. C
umella papillary, in some calices terminated by several stout kno

Fossil specimens obtained by me at station 3446, in the La C
marl, first deep cutting east of La Cruz, near Santiago, Cuba, dif

[1] Geol. Soc. London Quart. Journ., vol. 19, p. 435, 1863.

no noteworthy character from typical *S. siderea*. One specimen m this locality is 187 mm. across.

Localities and geologic occurrence.—Miocene: Jamaica, Bowden rl, received from Hon. T. H. Aldrich. Santo Domingo, Rio Cana, ne H, collected by Miss C. J. Maury. Cuba, La Cruz marl, tion 3446, near Santiago, collected by T. W. Vaughan.

Pleistocene: Canal Zone, at station 5849, Mount Hope; and Costa ca, station 6251, Monkey Point, collected by D. F. MacDonald; in Hill, Costa Rica, collected by H. Pittier.

This species is general in the Pleistocene and living reefs of the st Indies, eastern Central America, and Florida.

The stratigraphic range of *S. siderea* is from the horizon of the wden marl to the present.

8a. SIDERASTREA SIDEREA var. DOMINICENSIS, new variety.

Plate 114, figs. 4, 4*a*.

This variety differs from typical *S. siderea* by having much larger ices, which are as much as 6 mm. in diameter in a nearly hexagonal ice, and 4.5 by 8 mm. in diameter in a much deformed calice; and responding to the greater size of the calices, there are many quinary ta. Otherwise there seems to be no important difference, for the tal slopes, the septal dentations, the columellar pit, and the illary columella are about normal.

S. siderea var. *dominicensis* resembles *S. conferta* (Duncan) in sessing more than 4 cycles of septa, but according to the size of the ces the septa of *S. conferta* are more numerous, more crowded, l have more finely dentate septal edges; and the calices of *S. nferta* are shallower and more open.

Locality and geologic occurrence.—Haiti, living, collected by Lang- n, no more definite information.

Type.—No. 36909, U.S.N.M.

9. SIDERASTREA SILECENSIS, new species.

Plate 116, figs. 1, 1*a*, 2, 3; plate 117, figs. 1, 1*a*, 1*b*; plate 118, figs. 1, 1*a*.

? *Siderastrea silecensis* VAUGHAN, *nomen. nudum*, U. S. Nat. Mus. Bull. 90, p. 18.

The following is a description of the type of the species (pl. 116, g. 1, 1*a*):

Corallum massive, with domed upper surface. Greater diameter of specimen 170 mm.; lesser diameter 140 mm.; thickness, originally re than 85 mm.

Calices polygonal, separating wall usually slightly raised. The ipheral part of the septal margins is flattened, producing between acent calicular fossae a flat area which ranges from 0.5 to 1.5 mm. n width. Diameter of an adult calice, measured between the thecal

summits, 5 mm.; some oblong calices are as much as 7 mm. long 5 mm. wide. Depth of calices, 1.5 mm.

Septa, number in a calice 5 mm. in diameter, 50—i. e., 4 comp cycles and 2 quinaries; in a calice 6 mm. long and 4.5 mm. wide, number is 48, precisely 4 cycles. The usual number of sept 4 complete cycles, with a few quinaries in large calices. Around calicular margins the septa are subequal in size, the outer ends of quaternaries being only slightly smaller than those of the mem of the lower cycles. The interseptal spaces average slightly w than the thickness of the septa. Within the calices the prim and secondaries are only faintly larger than the tertiaries. The the usual septal fusion of tertiaries to secondaries and quaterna to tertiaries, but the tertiaries may almost or actually reach the c mella area while the quaternaries extend more than half way f the wall to the columella.

The upper flattened part of the septal margins is beaded; with distance of 1 mm., 5 rounded dentations were counted; between place where the septa drop downward in the calicular fossa and columella the number of dentations on the long septa is betwe and 10; the total number on the large septa is, therefore, betwee and 15. Synapticulae well developed, rather coarse, as woul expected from the relatively coarse septal trabeculae.

Columella weakly developed; upper surface papillary, but in m instances crossed by directive septa which meet in the corallite

Locality and occurrence of type specimen.—Station 3694, pine w Waukulla, Florida, T. W. Vaughan collector; Chattahoochee fo tion.

Type.—No. 325187, U.S.N.M.

The following is a description of a young, encrusting cor without a locality label, but almost certainly from the "silex" b Tampa, Florida. (See pl. 116, fig. 3.)

The calicular cavities are slightly excavated, between 0.75 a mm. deep; separated by intervening flattish areas which are fro to a little more than 2 mm. across and are faintly furrowed w adjacent corallites meet. The corallite wall may usually be r nized as a raised thread-like ridge in the intercorallite furrow. lite diameter from 5 to 6.5 mm.

Septa in 4 complete cycles with 6 or a few more quinaries i larger calices. The septal dentations are serrate or rounded, 13 on the long septa.

Columella with a papillary upper surface, but some calices considerable stereoplasmic deposit around the papillae with ten toward the formation of a compact columella.

A specimen from the "silex" bed at Ballast Point, Tampa, col by C. W. Cooke, has some calices that duplicate those of the spe

st described, but in other calices the septa and columella are thick-
ed, the columella in some calices being a more or less papillate
mpressed axial plug. The variation from the normal is similar to
e variation exhibited by the specimens of *S. siderea* from a depth
about 9 fathoms south of Tortugas, described on page 444.

Another specimen from Ballast Point has calices up to as large as
by 6.5 mm. in diameter. A large calice has 64 speta. Except in
ving rather large calices and correspondingly more septa, this
ecimen does not seem to differ in any important particular from
e type of the species.

Plate 117, figures 1, 1*a*, 1*b*, illustrates a variant from Coronet
osphate Mine, station No. 6043, G. C. Matson collector. The
ices in it are from 7 to a little more than 8 mm. in diameter. A
ice, 6.5 by 8 mm. in diameter, of this specimen has 66 septa.

A specimen from station 6084, Withlacoochee River, 3 miles below
ldosta, Lowndes County, Georgia, has in a calice 6 by 7 mm. in
meter 64 septa and in a calice 5.5 by 7 mm. in diameter 72 septa.
is specimen very closely approaches *S. conferta* (Duncan), but
pears to have on the average fewer septa than *S. conferta*. Perhaps
se specimens that have over 60 septa should be separated from
silecensis and either referred to a new species or to *S. conferta*.
one time I referred them to *S. conferta*, but their average fewer
ta according to the size of calices as compared with *S. conferta*,
me to consider them and the specimen next to be described as
onging to a different species.

*Description of a specimen from station 3381, Flint River, 4 miles
w Bainbridge, Georgia* (pl. 118, figs. 1, 1*a*).—Corallum subdiscoid
orm. Its greater transverse, diameter 45 mm.; lesser transverse
meter, about 38 mm.; thickness, 14 mm. Upper and lower sur-
e, subplane, somewhat undulated.

alices irregularly hexagonal or pentagonal in shape, fairly large,
ge in diameter from 4 to 6.5 mm.; rather shallow or superficial.

epta numerous, in one calice 6.5 mm. long by 4.5 mm. wide 58
e counted. There are, applying the ordinary method of distri-
ing septa into cycles according to the number, four complete
les and a fair number of members of a fifth. The various cycles
not distinctly marked. The septal margins in places slope from
acute ridge to the bottom of a moderately deep calice; in other
es the calices are shallow, superficial, the septal margins flat-
d from above, no ridge being present. The dentations on the
al margins are rounded; there are about 10 within 2 mm. Some
a are perforated between the trabeculae, but it seems probable
these perforations are of secondary origin, resulting from the
tion of the septa in the thinnest places during fossilization.

vnapticulae are very abundant, especially well developed in
ral, at least two or three, vertical series near the outer boundary

of the corallites. The boundary between adjoining calices is form
by a vertical row of synapticulae, considerably larger than the othe
Columella papillary, fairly well developed.

Localities and geologic occurrence.—Chattahooche formation, ba
part, station 3381, Little Horse Shoe Bend, Flint River, 4 miles bel
Bainbridge, Georgia, collected by T. W Vaughan: Chattahooch
formation, probably near the base, station 6084, Withlacoochee Riv
3 miles below Valdosta, Lowndes County, Georgia, collected by L.
Stephenson; Chattahoochee formation, upper part (stratigraphica
the same as the Tampa formation), station 3694, Waukulla, Flori
collected by T. W. Vaughan.

Tampa formation, the "silex" bed, Ballast Point, Tampa, statio
2115, collected by F. Burns; station 7754, an excellent specimen c
lected by C. W. Cooke.

Alum Bluff formation, station 6043 Coronet Phosphate Mine, n
Plant City, Florida, collected by G. C. Matson.

Specimens of this species have been obtained at other localities
Georgia and Florida in the Chattahoochee and Alum Bluff formatio
It is abundant around Alachua, Florida.

Siderastrea silecensis so closely resemble *S. conferta* (Duncan) t
for some time I referred the specimens of it to that species, but
calices of the same size the septa in *S. conferta* are more numero
more crowded, and thinner, and have more finely dentate marg
In a calice, 4.5 by 8.5 mm. in diameter, of a specimen of *S. confe*
from Antigua there are about 80 septa, a larger number than
counted in any calice of *S. silecensis*.

10. SIDERASTREA DALLI, new species.

Plate 119, figs. 1, 1*a*, 2.

Corallum forming a mass rounded above. The type has a lengt
about 122 mm. and is 75 by 82 mm. in diameter in its median p

The corallites are large, hexagonal or pentagonal in shape.
usual diameter is from 5 to 6.5 mm.; a large corallite is 5.75 b
mm. in diameter. Wall between the corallites usually distinct, t
Calices, shallow.

Septa, rather thin, or fairly thick, very crowded. There are
complete cycles and a fair number of the members of a fifth cy
The large calice, 5.75 by 8 mm. in diameter, has 68 septa.
septal grouping need not be described, as it is that common for
genus. Septal dentations fine, compressed transversely to the se
planes, finely frosted, from seventeen to twenty or more teeth on
members of the first cycle. No compound or double dentations
seen. The septal faces, closely granulate: perforations simila
those in *S. pliocenica*.

Synapticulae in three or four vertical rows—in the outer portion of e interseptal loculi, there may be even more. Very thin, nearly orizontal dissepiments present. The wall is similar to that of *pliocenica*, but thinner.

Columella, papillary. The papillae are fine, more delicate than in *pliocenica*.

Locality and geologic occurrence.—Florida, station No. 3300, ell Creek, collected by F. Burns (type); station 2094, Caloosa-tchee River, Florida, collected by W. H. Dall; Pliocene.

Type.—No. 325196, U.S.N.M. (pl. 119, figs. 1, 1*a*).

Paratype.—No. 325195, U.S.N.M.

This species is separated from *S. pliocenica* by its generally more elicate structure, more numerous septal dentations, and more umerous septa. It differs from *S. siderea* (Ellis and Solander) by s larger and shallower calices and its more numerous septa.

The closely crowded, transversely compressed, and finely frosted ptal dentations of *S. dalli* give it an appearance very different om any other American species of *Siderastrea*. The number of pta is in corallites of the same diameter about the same as in ecimens of *S. silecensis*.

11. SIDERASTREA CONFERTA (Duncan).

Plate 117, fig. 3; plate 120, figs. 1, 2, 2*a*, 3, 4; plate 121, figs. 1, 1*a*, 2, 2*a*.

1863. *Isastraea conferta* Duncan, Geol. Soc. London Quart. Journ., vol. 19, p. 422, pl. 14, fig. 2.

1867. *Isastraea conferta* Duncan, Geol. Soc. London Quart. Journ., vol. 24, p. 25.

The original description of *Isastraea conferta* is as follows: "Coral-les very close, tall, slender, straight, and prismatic; a transverse ction shows the wall to be very thin. The breadth of the corallites ries from three-tenths to one-tenth inch [=7.5 to 2.5 mm.]. pta very numerous; linear; the primary extend to the centre of e corallite, the secondary less so, and the others join the larger pta at a very acute angle; all are very slender and excessively owded. There are eighty-two septa in the larger corallites, sixty the smaller. The septa of one corallite do not join those of the xt, but end sharply at the wall. Endotheca plainly exists, linear, pearing, in transverse section, to divide the interseptal loculi o several cells. The reproduction is by submarginal budding. e sclerenchyma has been replaced by dark homogeneous silica, d the interspaces by porcellanous and opaline silica.

"From the Chert-formation of Antigua. Coll. Geol. Soc.

"This is a very remarkable form. Unfortunately no calices exist; t the transverse view of the corallites is excellent. If the specimen

had been found in Oolitic rocks, it would have passed for a sm
variety of *Isastraea tenuistriata*."

I examined the type of this species in the Geological Society
London collection (No. 12,929), and it is represented by plate 1
figure 1. It belongs to the genus *Siderastrea*. There are m
than four cycles of septa. The septal trabeculae are narrow,
produce fine dentations on the septal margins. The estimated num
of teeth on the margins of the longer septa is about 20; the syn
ticulae are fine and are crowded in two or three rings near the w
which is narrow and continuous. The columella is weakly develo
and evidently had a finely papillary upper surface.

I collected in Antigua, station 6888, one-half mile north of McE
non's mill, in the Antigua formation, one satisfactory specimen
this species. It is of massive, subcolumnar growth form, is ab
105 mm. tall, and is 82 by 92 mm. in diameter near the top.
basal part is appreciably narrower than near the summit.
calices are shallow; corallite walls thin. A calice 4.5 by 8.25 in di
eter has about 80 septa. Septa composed of small trabeculae
correspondingly have finely dentate margins. Synapticulae deli
and crowded.

This species is very abundant in the Oligocene deposits of the W
Indies and the Canal Zone. Description of or notes on specim
from the different localities follow. The next specimen to be
scribed is essentially typical, and as it is in a better state of prese
tion than the one from Antigua, it is more satisfactory for purp
of illustration.

Description of a specimen from near Lares, Porto Rico (pl.
fig. 2, 2*a*).—Corallum massive, rounded above, basal portion so
what expanded. Greater diameter of base, 106 mm.; lesser diam
of base, about 65 mm.; height, 65 mm.

Calices polygonal, rather large, diameter (measured from sum
to summit of wall) from 4.7 to 7.4 mm., 5 to 6 mm. the u
diameter. Near the edges the calices are shallow, higher up on
corallum they are excavated and moderately deep. The outer
of the septa are arched on the upper part of the corallum, may
somewhat flattened near the wall; lower down they may be depre
across a wide area, with a very shallow calicular cavity; in a
instances a depression corresponds in position to the upper edg
the wall. Wall usually distinct, narrow, zigzag.

Septa very crowded, thin and numerous, 70 in a calice 4.6 by
mm. in diameter, 76 in one 5.75 by 7.6 mm., 74 in one 5.5 by 6.3
in diameter. They are so crowded that it is difficult to make
the cycles. The primaries appear to be free, the other septa f
groups around the secondaries. Septal margins finely bea
about 26 dentations on a large septum, an actual count for an e

tal length could not be made, but 6 teeth within 0.7 mm. were nted on the outer part of a septum. This would be more than 8 h to 1 mm. Synapticulae abundant.

olumella not greatly developed: upper surface finely papillary.

collected at Crocus Bay, Anguilla, a suite of 22 specimens very ely similar to the Porto Rican specimen. Several of these are strated by plate 117, figure 3; plate 120, figures 3, 4; and plate , figures 2, 2*a*. The calice represented by plate 117, figure 3, is by 6.6 mm. in diameter, and has 68 septa; the larger calice illus- ed by plate 120, figure 3, is 7 by 9.5 mm. in diameter, and has 91 a; the calice illustrated by plate 120, figure 4, is 5.5 by 7.3 mm. iameter, and has 64 septa; and one of those figured on plate 121, re 2*a*, is 4.5 by 6.3 mm. in diameter, and has 75 septa.

pecimens of what seem undoubtedly to belong to the same species e collected in the Culebra formation, station 6020*c*, near Las adas, by Doctor MacDonald and me. Some specimens are as h as 14 inches (about 36 cm.) tall, and over 12 inches (about 31 thick. A part of the surface and an enlarged view of the calices represented by plate 121, figures 1, 1*a*. A calice 4 by 5.7 mm. iameter has about 72 septa.

specimen collected by Gabb in Santo Domingo and identified by rtalès as *Siderastraea siderea*[1] belongs to this species. The speci- has numerous thin, crowded septa; there are about 82 septa in a e 4.5 mm. wide and 6.5 mm. long. It is the property of the eum of Comparative Zoology, Harvard University.

calities and geologic occurrence.—Island of Antigua, Antigua for- ion, Duncan's type; station 6888, one-half mile north of McKin- s Mills, collected by T. W. Vaughan.

orto Rico, Pepino formation, station 3191, 4 miles west of Lares, lected by R. T. Hill.

nal Zone, Culebra formation, station 6020*c*, at Las Cascadas, lected by T. W. Vaughan and D. F. MacDonald.

land of Anguilla, Anguilla formation, stations 6893, 6894, 6966, r and middle beds, south and west sides of Crocus Bay, collected . W. Vaughan.

has been remarked, *S. silecensis* Vaughan from Georgia and da is very close to *S. conferta*. In calices of the same size there nore septa and the septa are more finely dentate in *S. conferta* in *S. silecensis*.

Family OULASTREIDAE, new family.

ngid corals with the superficial aspect of the genera belonging to family Orbicellidae. Corallites with distinct margins, usually ated by intercorallite areas that are crossed by confluent or

[1] Geol. Mag., new ser., dec. 2, vol. 2, p. 545, 1875.

alternating septo-costae. Septa lamellate but irregularly more or perforate. Both synapticulae and dissepiments present. Colun trabecular. Asexual reproduction by intercalicular gemmation.

The coral genera represented by *Oulastrea* Milne Edwards Haime, *Diploastrea* Matthai, and *Cyathomorpha* Reuss appear t to deserve recognition as a group of family value. The latter of these genera have been confused with *Orbicella*, as will be evident in subsequent remarks. It is unfortunate that the val of neither *Cyathomorpha* nor of *Diploastrea* can be establishe present. The reasons for the uncertainty will appear in discus to follow.

Oulastrea crispata (Lamarck) Milne Edwards and Haime, the species of *Oulastrea*[1] is represented in the United States Nat Museum by 30 specimens from Puerto Princesa, Palawan, coll by J. B. Steere, and from near Mariveles, Luzon, collected by A M. Reese, Philippine Islands. The description and figures give Milne Edwards and Haime are really excellent, but they did not ognize that the genus belongs to the Madreporaria Fungida. septa are mostly solid, but there are some perforations, especia the smaller septa. The walls of the corallites are synapticulate perforate around the periphery of the corallum, but those o interior corallites are continuous, with few or no obvious perfora There are synapticulae between the peripheral septo-costae; withi corallite cavities synapticulae mostly occur near the inner edg the septa, but some occur between the wall and the inner s edges. Thin dissepiments are abundant. The septal teeth us make two fairly definite, in some very definite, palar crowns stand a little higher than the columellar papillae. These speci are stained black and do not bleach when boiled with caustic po

As *Oulastrea* is the only genus referred to the family of the va of whose name I can be reasonably certain, notes on the generic acters are given in some detail.

Genus CYATHOMORPHA Reuss.

1868. *Cyathomorpha* Reuss, K. K. Akad. Wiss. Wien., Mat.-Naturwi Denkschr., vol. 28, p. 142, pl. 2, figs. 6*a*, 6*b*, 6*c*.
1884. *Cyathomorpha* Duncan, Linn. Soc. Lond. Journ. (Zool), vol. 18, p.
1889. *Cyathomorpha* Reis, Bayer. geognost. Landesuntersuch. Geognost. Ja Jahrg. 2, p. 147, pl. 3, figs. 17–19.

Type-species.—*Cyathomorpha conglobata* (Reuss) Reuss = *rochettina* Michelin = *Cyathomorpha rochettina* (Michelin) Reis, *fide*

[1] Comptes Rend., vol. 27, p. 495, 1848; Ann. Sci. nat., ser. 3, Zool., vol. 10, pl. 9, figs. 4, 4*a*, 184 vol. 12, p. 116, 1849.

[2] Bayer. geognost. Landesuntersuch. Geognost. Jahresh., Jahrg. 2, p. 147.

As the validity of this genus name is in doubt the following marks will be made on genera that appear to be either closely lated or synonymous.

Brachyphyllia Reuss: *type-species*, *B. dormitzeri* Reuss.

In the first of the publications cited in the footnote [1] below euss described and referred the following species to *Brachyphyllia: depressa*, *B. dormitzeri*, and *B. glomerata*. In the second paper [2] ed Reuss proposed the name *Agathiphyllia*, referred *Brachyphyllia pressa* to it, and said "der Typus der Gattung *Brachyphyllia* bleibt thin fortan *Br. dormitzeri* Rss. * * * Sie wird durch die viel meren Zellensterne, die dünneren, am obern Rande gleichmässig n gezähnelten Radiallamellen und die wenig entwickelte, sehr nkörnige Axe charakterisirt."

Agathiphyllia Reuss: *type-species*, *A. explanata* Reuss.

Reuss originally referred three species to *Agathiphyllia:*[2] *A. pressa* (Reuss) Reuss (first placed in *Brachyphyllia*), *A. conglobata* euss, and *A. explanata* Reuss. In 1868,[3] *A. conglobata* and one cimen previously referred to *A. explanata* are combined under *A. conglobata*, and made the type-species of a new genus, *Cyathomorpha*, ich is separated from *Agathiphyllia* by possessing a conspicuous ar crown. This procedure left two species, *A. depressa* (Reuss) d *A. explanata* Reuss, in *Agathiphyllia*. Reuss does not actually signate a type-species for *Agathiphyllia*, but, as he says, "Die ttung *Agathiphyllia* dürfte sich daher auf die l.c.[4], Tab. 2, Fig. 9 abgebildete *A. explanata* beschränken," I take *A. explanata* as genotype, excluding the misidentified specimen of *A. conglobata*.

n an endeavor to ascertain the generic characters of *Brachyphyllia*, ourse, *B. dormitzeri* must be studied. As there is no specimen of t species in the United States National Museum, Reuss's original cription and the later one by Felix [5] were consulted, but neither the details of the structure and mode of formation of the wall or he septa, nor is the character of the endotheca given. At present t not known whether *Brachyphyllia* is an imperforate coral belong- to the family Orbicellidae, or whether it is a fungid coral, related to he same as *Cyathomorpha*.

Duncan [6] refers *Agathiphyllia* to the synonymy of *Cyathomorpha* hout giving any reason for adopting the later instead of the earlier me. The type-species of *Agathiphyllia*, *A. explanata* Reuss, is m Oberburg, Styria. According to the figures, *Agathiphyllia* has the wide paliform lobes of *Cyathomorpha;* but critical study of

[1] K. K. Akad. Wiss. Wien., Mat.-Naturwiss. Cl., Denkschr., vol. 7, p. 103, 1854.
[2] Idem. vol. 23, p. 14, 1864.
[3] Idem. vol. 28, p. 143, 1868.
[4] Idem. vol. 23, p. 15, 1864.
[5] Palaeontographica, vol. 49, p. 260, 1903.
[6] Linn. Soc. London Journ. (Zool.), vol. 18, p. 105, 1884.

authentic specimens of the type-species is needed to ascertain whetl the genus is or is not a fungid coral.

At present neither *Brachyphyllia* nor *Agathiphyllia* can be identifi

Cyathomorpha is a fungid genus that has the general appearance f *Orbicella*, with which it has been confused.

The next description is of the genotype.

CYATHOMORPHA ROCHETTINA (Michelin) Reis.

Plate 123, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 1*e*.

1840–1847. *Astrea rochettina* Michelin, Icongraph. Zoophytol., p. 58, pl. 12, fi
1889. *Cyathomorpha rochettina* Reis, Bayer. geognost. Landesuntersuch. G nost. Jahresh., Jahrg. 2, p. 147, pl. 3, figs. 17, 19. (With synonymy

There is in the United States National Museum one young specin (No. 156900), from Crosara, Italy, received from the K. K. Muse für Naturkunde, Berlin. Plate 123, figures 1, 1*a*, 1*b*, presents a vi each of the upper surface, of the side, and of the lower surface of t specimen, natural size.

On the base and in places on the sides of the corallum the edge superposed layers are clearly seen, the lower edge of the outer la often flaring somewhat. There are prominent, steep-sided, dist costae, crossed by transverse carinae; distance between costal cr usually ranges from about 0.75 to 1.5 mm. In places the course these costae are interrupted by what morphologically corresponds septal perforations. Between the larger are small costae, which the most part are represented by rows of spines. Exothecal sepiments are present. The walls in general appear solid, but r the upper edges synapticulae and intercostal pits or perforations distinguishable. The spines, trabeculae, of the small costae in pl are joined to the large costae by synapticulae.

The larger septa are imperforate, at least for the most part, but last two or three cycles are clearly perforate, composed of imperfe fused trabeculae. Faces of large septa with carinae; synaptic well developed, especially near the columella.

Columella large, trabecular; upper surface papillary.

The foregoing notes are not intended as a description of the spe their object is to emphasize the fact that *Cyathomorpha* is a fu coral and to indicate its important generic characters. Reis[1] re nized the presence of synapticulae in this species but did not ref to Madreporaria Fungida.

Localities and geologic occurrence.—Castel Gomberto, Crosara, Sassello, Italy; Reit-im-Winkel, Bavaria; lower to middle Oligoc

[1] Bayer geognost. Landesuntersuch. Geognost. Jahresh., Jahrg. 2, p. 147, 1889.
[2] Idem., pp. 93, 94.

CYATHOMORPHA HILLI, new species.

Plate 124, figs. 1, 1*a*; plate 125, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 2, 2*a*.

Corallum with a small base, above which it increased in diameter; per surface rounded; calices confined to the upper curvature; se and sides below the level of the calices naked, not even shreds epitheca were observed. Below the calices, the sides of the coral- n grow outward by the superposition of costate layers, each outer er resting on the costae of the next inner layer, except at the ver edge where it may flare outward. The layers range in thick- s from 0.5 and 1.5 mm.; usually they are imperforate, but in ces perforations and synapticulae can be clearly recognized. e costae are narrow, steep-sided, fairly prominent, acute or nded on the edges; distance between costal summits from 0.75 to mm. The type is 112 mm. in horizontal diameter and 80 mm. tall. orallites protuberant from 1.5 up to more than 10 mm., average r 6 mm.; distance between thecal summits of neighboring coral- s from 3 to 10 mm., or even more. Corallite walls with a rather rp upper edge; mostly imperforate. Some perforations and apticulae, especially near the upper edges. Septo-costae low, equal, wide, flattish or rounded in profile.

alices subcircular, broadly elliptical, or compressed elliptical in line. A large subcircular calice on the type is 18 mm. in diam- ; a small, but apparently fully developed calice, on the same imen, is 10 by 13 mm. in diameter; the shorter diameter of ng calices is only 8 mm. The calices of the type are larger than e of the other specimens of the species. In paratype No. 1 125, fig. 1), the largest calice is 11.5 by 13.5 mm. in diameter; smallest is 8 by 13 mm. in diameter. In paratype No. 2 (pl. 125, 2), the largest calice is 13.5 by 16.5 mm.; the smallest, 10 mm. iameter. Unless the calices are young or stunted the average e two diameters is rarely below 10 mm. Depth of calices slight, t 4 mm. a maximum; columellar fossa not deep.

ne number of septa in the calice represented by plate 125, fig. 1*c*, type No. 1, is 70. This calice is 11.5 by 13.5 mm. in diameter, is of the size about normal for the species. It has four com- cycles of septa and 22 quinaries. About 8 of the septa are ker than the others, and bear thick paliform lobes which are l half the width of the septa. These 8 septa and about 15 ner septa extend to the columella; the thinner septa also bear paliform lobes. In general in a half or quarter system the pt of the penultimate cycle fuse to the sides of the included mem- of the next lower cycle, while the members of the last cycle are . All except the smallest septa bear paliform lobes. Septal ins low over the wall, subentire; within the calice the thicker

septa have subentire margins, the thinner septa have decide dentate edges. Larger septa solid; the thinner ones, especia those next to the last cycle, considerably perforate; septal fa granulate.

Synapticulae well developed, especially near the wall and n the columella; very obvious near the inner fusion of the sep groups. Some thin dissepiments present.

Columella rather coarsely trabecular, well developed, appro mately one-third the diameter of a calice; upper surface sunker a shallow central fossa.

Asexual reproduction by intercalicular budding.

Locality and geologic occurrence.—Antigua, in the Antigua for tion, at stations 6881, Willoughby Bay (type and paratypes); 68 Rifle Butts; 6856, south side of Friar's hill; 6888, one-half n north of McKinnon's mill, collected by T. W. Vaughan.

Type.—No. 325204, U.S.N.M.

Paratypes.—No. 325205, U.S.N.M. (2 specimens).

That *Cyathomorpha hilli* is very nearly related to *Cyathomor rochettina* (Michelin) Reis, is shown by a comparison of the desc tions and figures here presented. *C. browni*, the next species t described, differs from *C. hilli* by its prominent, acute costae, by its septa higher than the second cycle being more strongly di entiated according to cycles.

It gives me pleasure to attach the name of Mr. Robert T. Hi this handsome species.

CYATHOMORPHA BROWNI, new species.

Plate 126, figs. 1, 1*a*, 1*b*.

This species is similar to *Cyathomorpha hilli* in the general as of the corallum. It differs principally in having prominent, a costae corresponding to all except the last cycle of septa, to w the corresponding costae are either very small or obsolete.

The calices range from about 8 to 13 mm. in diameter; ave size smaller than in *C. hilli*.

In a calice 12.5 mm. in diameter there are 4 cycles of septa in some systems the fifth is complete but it is represented by s thin, rudimentary septa. Primaries and secondaries subeq tertiaries and quaternaries shorter and thinner according to cy All septa except the last cycle bear thickened paliform lobes. septa are thinner and the interseptal spaces relatively wider in *C. hilli*.

Synapticulae present near the wall and near the inner ends o septa. Apparently some thin dissepiments present.

Locality and geologic occurrence.—Antigua, in the Antigua f mation, stations 6888, one-half mile north of McKinnon's mill (

d three other specimens); 6868, Pope's Saddle, collected by W. Vaughan.

Type.—No. 325211, U.S.N.M.

This coral may ultimately be shown to intergrade with *Cyathorpha hilli*, but according to the specimens available for study ey are distinct.

Cyathomorpha browni is named for Prof. Amos P. Brown who paid nsiderable attention to the paleontology of the Central American l West Indian Tertiary formations.

CYATHOMORPHA BELLI, new species.

Plate 128, figs. 1, 1*a*, 1*b*.

Corallum more or less explanate, rounded above and flattish below; e without epitheca, similar in this character to *C. rochettina*.

Calices large, 11.5 mm. a usual measure of the diameter, range in meter from 7.5 mm. (a small calice) to 12.5 mm.; distance apart n 3.5 to 10.5 mm.; calicular rims elevated up to as much as m., usually lower on the distal than on the proximal side. Calar cavities relatively shallow in comparison with the diameter, th about 2.5 mm. Corallite walls with few or no perforations ept at the upper edge; appear to be originally synapticulate and sequently compacted.

Costae at the calicular edge subequal or slightly alternating in , corresponding to all septa; but just below the calicular edge costae corresponding to the last cycle of septa tend to decrease ize and usually disappear at the base of the free corallite limb, le the costae corresponding to the lower cycles of septa tend to ease in height and extend as rather prominent plates on to or n across the intercorallite areas. Costal edges with low beading.

he septa in a calice 10 mm. in diameter are only 46 in number; in her calice 9.25 by 13 mm. in diameter there are 48 septa. efore, in comparison with the size of the calices, there are relly few septa, barely four cycles. In general the following is septal arrangement: primaries and secondaries extend to the lumella, and have a circle of single or double paliform lobes; aries extend to or almost to the columella, but are thinner the primaries and secondaries, and many bear a paliform lobe the columella; the quaternaries are shorter and thinner, some ese bear pali. Over the mural summit the margins of all septa ubequally slightly exsert, about 0.6 mm. is a maximum, average een 0.25 and 0.5 mm. Large septa solid; higher cycles with rations. Septal arch a gradual curve. Margins with some ations.

Columella large, about 3 mm. in diameter or nearly one-third the eter of the calice, trabecular, more or less whorled.

Synapticulae present, especially near the columella. Endothe
dissepiments highly developed and vesicular.

Locality and geologic occurrence.—Antigua, station 6854, R
butts, Antigua formation, collected by T. W. Vaughan.

Type.—No. 325218, U.S.N.M.

This species is dedicated to His Excellency Sir H. Hesketh B
Governor of the Leeward Islands at the time I collected in Anti
and other Leeward Islands. It was to his helpfulness that
success of my work was largely due.

On page 389 of this paper attention is directed to the resembla
between *Orbicella costata* (Duncan) and *Cyathomorpha belli*.

CYATHOMORPHA SPLENDENS, new species.

Plate 128, figs. 2, 2*a*, 2*b*.

Corallum unifacial, calices on the upper surface; base naked, w
wide, low costae. Maximum thickness of type 24.5 mm.; thickn
to base of corallite 15 mm.

Calices shallow, but excavated; diameter, 17.5 by 20 mm.; ma
elevated 4 mm. on one side, 9 mm. on the other side. Strong subeq
costae correspond to all septa except those that are rudimentary

Septa 54 in number, the quinaries rudimentary; primaries a
secondaries larger than the septa of higher cycles.

Columella large, 8 mm. in diameter, surface coarsely papillate.

Dissepiments greatly developed; synapticulae present.

Locality and geologic occurrence.—Antigua, station 6854, in
Antigua formation, Rifle Butts, collected by T. W. Vaughan.

Type.—No. 325219, U.S.N.M.

The description of this species is brief, because a more elabo te
one would be largely a repetition of what has been said under he
four preceding descriptions. The most nearly related specie is
C. belli, from which it differs by the wider and lower costae o ts
lower surface, its much larger calices, and, in comparison with he
size of the calices, its fewer septa.

CYATHOMORPHA ANGUILLENSIS, new species.

Plate 127, figs. 1, 2, 3, 4, 5.

This species is usually characterized by its large, distant, and pr n-
inent calices.

Dimension of calices of Cyathomorpha anguillensis.

	1	2	3	4	5	6	
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*n.*
Greater diameter	18.5	15	12	14.5	15	14	11
Lesser diameter	14.5	14.5	12	12.5	14	12.5	9.5

The young calices, of course, are smaller.

Distance apart 7 to 20 mm. Isolated calices may be decidedly rominent, 5 mm. or more in height. Depth, moderate.

The corallites externally are strongly costate: large, tall, thin ostae alternate with much smaller ones. The intercostal spaces ider than the costae. Wall mostly dissepimental, but there are me synapticulae with intervening perforations similar to those in *. rochettina*.

Septa in the larger calices between 70 and 80, the various systems d cycles are not distinctly differentiated, about 24 reach the lumella. Within the wall the septa are thin, in the thecal ring ey are thicker; the costae are thicker than the inner portions of the pta. Pali before the members of the first three cycles of septa. th synapticulae and dissepiments present.

Columella large, composed of twisted, interlacing, fused inner ends septa. Its diameter about one-third the diameter of the calice.

Localities and geologic occurrence.—Island of Anguilla, West Indies, llected by P. T. Cleve; station 6969*a*, bottom bed, Road Bay, nguilla, collected by T. W. Vaughan.

A specimen from station 7509, west of Ocujal Spring, conglomerate ulder on hill of limestone conglomerate, near Guantanamo, Cba, collected by O. E. Meinzer, seems to be referable to this species: is a large calicled species of *Cyathomorpha*, and I have found no fferences between it and *C. anguillensis*.

Type.—University of Upsala (pl. 127, fig. 1); 4 specimens in the ited States National Museum.

Three specimens belonging to the University of Upsala collection a typical, although they show some variation. Four other speciens show gradual decrease in both the size and prominence of the ce. These four specimens are figures on plate 127, figures 2, 3, 4 5. With them before one it does not seem possible to separate sharply the large and prominent caliced specimens from those with smaller (7 mm. diameter) and only slightly prominent calices.

he specimens with smaller, less prominent calices closely resemble tl specimens described below under the name *C. roxboroughi*.

CYATHOMORPHA ROXBOROUGHI, new species.

Plate 129, figs. 1, 1*a*, 1*b*.

orallum massive, usually rather broadly and obtusely conical in sh e. Type—greater diameter of base, 111 mm.; lesser diameter of ase, 73 mm.; height, 103 mm. The rather large difference in the ba l diameters is probably in part due to compression. A paratype ha a greater basal diameter of 121 mm.; lesser basal diameter, 10 mm.; height, 96 mm. Base without calices; apparently some

shreds of epitheca. Costae of base, low, rather crowded, subequal, with clearly visible synapticulae between them.

Calices very shallow, quite or almost superficial, with margins ranging from flush with the intercorallite areas up to 3.5 mm. or more in height. In some corallites the free limb on the lower side is from 6.5 to 9 mm. long, while the margin of the upper side is only slightly elevated. The calicular outline is subcircular or broadly elliptical; the diameter ranges from 6 to 10 mm., 8 to 9 mm. usual for fully developed calices. Distance between calicular rims ranges from 4 to 13 mm. Intercalicular area flattish except near the peripheries of the calices where they slope upward rather steeply if the calices are elevated. Septo-costae correspond to all septa and are subequal at the calicular margins; lower down they are either subequal, low, broad, and with flattish or rounded summits, or they alternate in prominence: where there is such alternation the edges are usually acute. Transversely compressed granulations on some septo-costae, but usually the margins are almost smooth. The septo-costae are confluent between adjacent corallites or meet at a sharp angle; outer limits of corallites usually marked by a circumscribing ridge that joins adjacent septo-costae. Synapticulae distinct between the septo-costae, in both transverse and longitudinal sections. Walls with synapticulae near the upper edge.

Septa thick, lanceolate, in the wall, rapidly thinning within the calicular cavity. In a calice 8 mm. in diameter there are 38 septa, every other one of which extends to the columella. There are strongly developed, thick, prominent pali on the inner ends of all unbroken long septa, obscurely arranged in two crowns. Unless decidedly small the septa of the last cycle fuse to the sides of the septa of the next lower cycle; in some systems tertiaries fuse to secondaries and quaternaries to tertiaries. Septal margins subentire or obscurely denticulate. Usually the lamellae are solid, but broken transverse sections of the corallites of a specimen not the type show some perforations. Synapticulae well developed.

Columella large, coarsely trabecular, in the center of the shallow flat-bottomed calice.

Asexual reproduction by intercalicular gemmation.

Locality and geologic occurrence.—Anguilla, at the following stations: 6962, 1 mile northeast of Boat Harbor (type); 6893, Crocus Bay on roadside from Valley Post Office down the bluff (7 specimens); 6894, west side of Crocus Bay, probably from the lower part of the exposure (paratype); 6963, west side of Sandy Hill (2 specimens), collected by T. W. Vaughan. Professor Cleve obtained at least one and I obtained 11 identifiable specimens of this species in Anguilla.

Type.—No. 325250, U.S.N.M.

Paratype.—No. 325248, U.S.N.M.

This is the species to which I referred as *Diploastrea* from the lowest rizon of the exposure at Crocus Bay, Anguilla, in discussing the nus *Diploastrea* in my paper entitled: Some shoal-water corals m Murray Island (Australia), Cocos-Keeling Islands, and Fanning and.[1] My remarks particularly applied to the paratype from sta- n 6894.

Cyathomorpha roxboroughi closely resembles those specimens of *anguillensis* with smaller calices.

C. roxboroughi is named for His Honor T. L. Roxborough, who was ministrator of St. Christopher while I was there and to whom I indebted for many acts of courtesy and kindness.

CYATHOMORPHA ANTIGUENSIS (Duncan) Vaughan.

Pl. 129, fig. 2; plate 130, figs. 1, 1*a*, 2, 2*a*, 3; plate 131, figs. 1, 1*a*, 1*b*, 2, 3, 4; plate 132, figs. 1, 2, 2*a*, 2*b*; plate 133, fig. 1.

1863. *Astraea antiguensis* Duncan, Geol. Soc. London Quart. Journ., vol. 19, p. 419, pl. 13, fig. 8.

1863. *?Astroria affinis* Duncan, Geol. Soc. London Quart. Journ., vol. 19, p. 425.

1863. *Astroria antiguensis* Duncan, Geol. Soc. London Quart. Journ., vol. 19, p. 425.

1866. *?Astroria affinis* Duchassaing and Michelotti, Sup. Corall. Antilles, p. 83 (of reprint).

1866. *Astroria antiguensis* Duchassaing and Michelotti, Sup. Corall. Antilles, p. 83 (of reprint).

1866. *Heliastraea antiguensis* Duchassaing and Michelotti, Sup. Corall. Antilles, p. 86 (of reprint).

1867. *?Astroria affinis* Duncan, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

1867. *Astroria antiguensis* Duncan, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

1867. *Heliastraea antiguensis* Duncan, Geol. Soc. London Quart. Journ., vol. 24, p. 24.

1870. *?Astroria affinis* Duchassaing, Rev. Zooph. Antilles, p. 30.

1870. *Heliastraea antiguensis* Duchassaing, Rev. Zooph. Antilles, p. 30.

1870. *Astroria antiguensis* Duchassaing, Rev. Zooph. Antilles, p. 30.

his species was referred by me doubtfully to the synonymy of *Oculina cavernosa* (Linnaeus) in my Fossil Corals from the Elevated Reefs of Curacao, Arube and Bonaire,[2] not having recognized at th time that the species is one of the Madreporaria Fungida.

riginal description.—"Corallum large, turbinate, convex and gil ous above, with a very small base. Corallites long, close, rather cr ded, but distinct and radiating from the narrow base. Walls we developed, moderately thick. Costae moderately developed, pr ecting more than the width of their base; they are plain where see superficially, very nearly equal, and are not spined or toothed. In ome corallites the fourth cycle of costae is wanting, but not in the that are fully developed. Calices circular, slightly raised,

[1] Carnegie Inst. Washington Pub. 213, p. 142, 1918.

[2] Geologisch. Reichs. Museum Leiden Samml., ser. 2, vol. 2, p. 28, 1901.

appearing as truncated cones, sometimes compressed (at the s
of the corallum they are distorted), unequal in size; margins t
Fossa not deep, but variable. Columella well developed, projec
at the bottom of the fossa; its component tissue is laminar and fol
and it is rounded above. Septa straight, very slightly exsert, deli
throughout, not larger at any point decidedly; but the largest r
more delicate midway between the walls and the columella; they r
arranged in six systems of four cycles. The primary and secon
septa are equal; the tertiary a little smaller; those of the fo
order are very small, and barely developed in some calices, but
exist in all. The primary and secondary septa have a tooth
the columella. Endotheca tolerably developed. Exotheca
developed, forming large and small cells, both square, though o
divided by dissepiments. Reproduction by extracalicular gem
tion. There is no epitheca.

"*Dimensions.*—Height of corallum several inches; diamete
calices from a little less than 3 lines to 4 [6.25 to 8.3 mm.]; thick
of septa one-sixtieth inch [0.4 mm.]. The dimensions of the
tical calices are—length, 3½ lines [7.3 mm.]; breadth, 2½ lines [5.2 m
depth of fossa, two-thirds of a line [1.4 mm.]. Exothecal cells
one-fourth to one-half line [0.5 to 1 mm.]. The lateral calices
very irregular, and the younger corallites have three cycles of se

"*Fossillization.*—Calices, as a rule, not filled up. Sclerench
light-brown in color, opaque, and siliceous, the central portio
the corallum evidently consisting of dark homogeneous flint, he
sclerenchyma having been destroyed in the process of silicificati

"From the Marl-formation of Antigua. Coll. Geol. Soc."

Plate 130, figures 2, 2*a*, presents illustrations of Duncan's type
12942, collection of the Geological Society of London). Du
was of the opinion that this species belonged to the genus *Helias*
Milne Edwards and Haime, which is a synonym of *Orbicella* D
It was my belief that the species was referable to *Orbicella* un
obtained a number of remarkably good specimens in Antigua
selected series of these will be described in the following remar

The corallum forms rounded or discoid masses, the two larg
collected having the following dimensions: No. 1, horizontal diam
225 by 305 mm.; height, 155 mm. No. 2, horizontal diameter, 3
400 mm.; height, 131 mm. Specimen No. 1 has a more a
upper surface than No. 2 which is more discoid in shape.

On the lower surface of the corallum there is very little epith
only shreds in places. Costae are well-developed, subequal, i
rupted here and there; intercostal furrows perforate, many sy
ticulae present, joining the outer ends of adjacent septa (see pl.
figs. 1, 1*a*).

The series of figures (pl. 131, figs. 1, 2, 3), shows the range in size, nape, depth, and distance apart of the calices. Except very young alices, which may be only 3 mm. in diameter, the range in iameter of these on the specimen represented by plate 129, figure 2, from 5.5 to 10 mm.; on the specimen represented by plate 130, gure 3, one calice is 12.5 mm. in diameter. In shape the calices 'e subcircular, elliptical, deformed elliptical, or, where crowded, olygonal. The depth ranges from superficial to as much as 4.5 mm. a little more, but on most specimens the calices are rather shallow. ie distance apart ranges from 0.75 mm. to nearly 10 mm. Plate 1, figure 3, shows polygonal crowded calices and distant circular lices on the same specimen. Costae subequal or slightly alternating, correspond to all septa. Their margins, where perfectly eserved, are beaded, in places interrupted. Unless the calices e very crowded, synapticulae are obvious between the costae. 'ie corallite walls are synapticulate and very perforate (see pl. 131, . 1*a*).

The septa are usually thin, in about 4 cycles, as many as 58 in ge calices. Primaries and secondaries subequal, extend to the umella; tertiaries rather long but usually do not reach the columa; quaternaries, and quinaries where present, are shorter. In ny calices some tertiaries fuse to the sides of the secondaries, and quaternaries may fuse to the sides of the tertiaries; but there is ch variation, in some systems there are no septal groups by fusion. e septal arches may be rather wide, the septal edges gradually ving over the calicular rim; or the arches may be narrow, the tal edges falling steeply to near the level of calicular bottom—h of these conditions occur on the same specimen. Primary and ondary septa appear imperforate, should there be perforations y are rare; higher cycles perforate. Septal faces with carinae and nulations. Margins of larger septa finely beaded; margins of mbers of higher cycles more conspicuously dentate. Prominent, ner wide, thickish, paliform lobes before the primary and secondsepta; an outer palar crown before the tertiary septa.

olumella fairly well developed, trabecular; upper surface papillary he best preserved calices.

ynapticulae abundant within the corallite cavities. Endothecal epiments also present.

sexual reproduction by intercalicular budding.

ocalities and geologic occurrence.—Antigua, in the Antigua formaat stations 6854, Friar's Hill; 6856, Rifle Butts; 6881, Willoughby ; 6888, one-half mile north of McKinnon's Mill, collected by T.V. Vaughan, a total of about 35 specimens.

orto Rico, in the Pepino formation, station 3191, 4 miles west of s, Porto Rico, collected by Robert T. Hill.

Cuba, station 7514, 5 miles east of monument H4 of U. S. Naval Reservation, Guatanamo, altitude 400 feet a. t., collected by O. E. Meinzer.

Mexico, in the San Rafael formation, 4 miles east of Salitre Ranch, State of Tamaulipas, collected by W. F. Cummins and J. M. Sails.

The foregoing description, except the measurements of the large specimens, is based entirely on the five specimens represented by plate 129, figure 2; plate 130, figures 1, 1*a*, 3; plate 131, figures 1, *a*. 1*b*, 2, 3. Two of these specimens, plate 129, figure 2 and plate 0, figures 1, 1*a*, 3, are from station 6881, Willoughby Bay; and the plate 131, figures 1, 1*a*, 1*b*, 2, 3, are from station 6854, Rifle Bats Antigua. The specimen from Salitre Ranch, Tamaulipas, Mexico, is so completely typical that no further notes on it are necessary. Two of the specimens from Porto Rico, plate 132, figures 1, 2, 2*a* 2*b*. have thicker primary and secondary septa, and the costae corresponding to the last cycle of septa seem usually to be small or even obsolete in places. The rear side of the specimen, general view, plate 132, figure 2, has calices and costae so nearly typical that it can scarcely be regarded as more than a variant of *C. antiguensis*.

The specimen from station 7514, near Guatanamo, represents the same variant as the Porto Rico specimens.

Duncan's *Astroria affinis*, I believe, is based on a specime of *Cyathomorpha antiguensis* that has crowded, polygonal corallites. Plate 133, figure 1, represents the type (No. 12938, Coll. Geol. Soc., London), and the following is the original description: "Corallites crowded. Walls very thin indeed. Transverse section of corallites polygonal, rarely forming short series. Columella slightly but decidedly developed. Septa alternately large and very small, linear, a little larger externally, with at least four cycles in six systems. Breadth of the calices four lines [8.4 mm.]; five septa to one line [2.1 mm.]. Endotheca abundant.

"From the Chert-formation of Antigua. Coll. Geol. Soc."

In my notes on the type, I say that *A. affinis* is undoubtedly the same as Duncan's *Astroria antiguensis* type (No. 12936, Coll. Geol. Soc. London), illustrated by plate 131, figure 4 of this paper; but I am not certain that it is different from *C. tenuis*. the species to be considered next. The original description is as follows:

"Corallites not crowded, but close, tall. Walls rather thin. The transverse section of the corallites is in many cases circular in others obscurely polygonal; some present short series, but rarely. Columella very indistinct. Septa alternately large and small, in six systems of four cycles, the fourth being occasionally deficient in two systems. Breadth of the corallites, from 2 to 3½ lines [4.2 to 7.3 mm.]. Length of the series, 6 lines [12.7 mm.]; five septa to a line [2.1 mm.]. Endotheca abundant.

"Fossilization like that of the other Astrorians, and rendering the etails indistinct. It is closely allied to the other species of *Astroria* om Antigua.

"From the Chert-formation of Antigua. Coll. Geol. Soc."

CYATHOMORPHA TENUIS (Duncan) Vaughan.

Plate 132, figs. 3, 3*a*; Plate 133, figs. 2, 3, 3*a*, 3*b*.

1863. *Astraea tenuis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 421, pl. 13, fig. 11.
1867. *Heliastraea tenuis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 24.
1901. *Orbicella tenuis* VAUGHAN (*part*), Geolog. Reichs Mus. Leiden Samml., ser. 2, vol. 2, p. 33.

This species, as well as *Astraea antiguensis* Duncan, was erroneously confused with *Orbicella* Dana. I obtained excellent material Antigua, which shows that both the common corallum wall and corallite walls are synapticulate. Three views of one of these ecies are given on plate 133, figures 3, 3*a*, 3*b*. Plate 133, figure 3, general view of the upper surface of the corallum; figure 3*b* shows synapticulate character of the common wall; and figure 3*a* illustes the costae and the synapticulae between them.

The following description is based upon four specimens collected Mr. Robert T. Hill at a locality 4 inches west of Lares, Porto. ey satisfy in all particulars Duncan's description of *C. tenuis* and er in no important particulars from the Antiguan specimens.

The corallum is pulvinate, with the calices confined to the upper face and sides.

Dimensions of specimens of Cyathomorpha tenuis (Duncan).

ecimen No.	Greater diameter.	Lesser diameter.	Height.	
	mm.	*mm.*	*mm.*	
[1]	69	52	55	Specimen apparently somewhat crushed.
	87	70	58	
[1]	100	100	45	Specimen subquadrangular in shape.
	126	97	64	

[1] Specimens figured.

he calices of specimen No. 1 (pl. 132, figs. 3, 3*a*) are described, ough those along the top have been somewhat deformed through al compression of the corallum. The calices on the upper part of e surface have slightly elevated margins; 0.75 mm. is the maximi height. Some calices are rather deep, about 2 mm.; the ameter of the most nearly circular ones ranges from 3.5 to very ghtly more than 4 mm.; the distance between adjacent calices is fro a mere dividing ridge to 2 mm.; the calicular edges, however, are usually distinct. Around each calice and joining adjacent ones are equal, acute costae, between which are synapticulae. On the

sides, near the lower edges, the calices flatten, become larger and more distant, and are either circular or faintly hexagonal in outline. Diameter from 4.5 to 5 mm.; distance apart, from 0.5 to 2 mm.; the range in the distance apart is the same as on the top, but the calices are more uniformly separated. The costae are distinct, strong and equal, with numerous intervening synapticulae.

The number of septa to a calice is the same for both the top and sides, ranging from 26 to a few over 30. They are relatively thin, that is, not so thick as the width of the interseptal loculi, except that they are thickened at the wall and the principals are thickened on their inner ends, bearing distinct paliform lobes. The primaries and secondaries are subequal, extend to the columella, and are palarous; tertiaries shorter and thinner within the calice; quaternaries where present, still smaller. The wall is composed of peripheral synapticulae.

Columella only slightly developed.

The preceding description is based on a single specimen—No. 1 of the table. The principal variation shown by the other specimens is in the distance apart and size of the calices and the number of septa. In specimen No. 3 (see pl. 133, fig. 2) the calices are usually about 0.75 mm. apart; their diameter ranges from 3.5 to 5.7 mm., and as would be expected, the calicular outlines are polygonal; there are in the larger calices as many as 40 septa, the fourth cycle, however, in these calices seems never to be complete, but it is complete in some large calices of the Antiguan specimens. Palar thickenings can be seen on the larger septa; columella poorly developed.

Localities and geologic occurrence.—Island of Antigua at numerous localities in the Antigua formation, collected by T. W. Vaughan.

Porto Rico, station 3191, in the Pepino formation, 4 miles west of Lares, collected by Robert T. Hill.

Cuba, station 3467, Canapu River, Manasas trail, collected by Arthur C. Spencer. Station 7511, between Ocujal and Palma, altitude about 500 feet a. t., near Guantanamo, Cuba, collected by O. E. Meinzer. Station 7514, 5 miles east of monument H4 of U. S. Naval Reservation, Guantanamo, Cuba, altitude 400 feet a. t., collected by O. E. Meinzer.

Prof. K. Martin, director of the Geologisch Reichs Museum, Leiden, submitted to me for determination some material from Arro Colorado, Aruba, that I thought referable to this species.[1] At the time I studied these specimens I was of the opinion the species belonged to the genus *Orbicella*. The specimens referred to *O. tuberosa* in the paper cited are referred in the present paper to *Antiguastrea cellulosa* (Duncan) Vaughan (see p. 407).

[1] Geolog. Reichs Mus. Leiden Samml., ser. 2, vol. 2, p. 33.

yathomorpha tenuis in some of its characters is very similar to *astrea*. In fact I have vacillated between referring it to *Cyathomorpha* or to *Oulastrea*, particularly as there is in the New York demy Porto Rican collection a species that resembles *C. tenuis*, is more appropriately referable to *Oulastrea* than to *Cyathomorpha*, and a specimen, poorly preserved but apparently the same cies, was obtained by Mr. Meinzer at Mogote Peak, east of the S. Naval Reservation, near Guantanamo, Cuba, in beds of the e age as those in which the Porto Rican specimen was collected. the Cuban material is not good enough for an accurate descrip-, the discussion of this interesting species must be deferred.

Genus DIPLOASTREA Matthai.

1914. *Diploastrea* Matthai, Linn. Soc. London Trans., ser. 2, Zool., vol. 17, p. 72.
1917. *Diploastrea* Vaughan, Carnegie Inst. Washington Pub. 213, p. 142.

ype-species.—*Astrea heliopora* Lamarck.

my paper cited in the synonymy I wrote "*Diploastrea* is one of most important genera of Oligocene corals in the southeastern ted States and in the West Indies. *Astraea crassolamellata* ican, from Antigua belongs to it. It is also found in the lowest zon at Crocus Bay, Anguilla; in Cuba at numerous localities; g Flint River near Bainbridge, Georgia; and in eastern Mexico." also remarked that *Diploastrea* might ultimately become a nym of *Cyathomorpha*. I am referring the Crocus Bay specimen *yathomorpha roxboroughi* Vaughan, new species (see page 461 of paper), and am referring the Mexican specimen to *Cyathomorpha quensis* (Duncan) Vaughan (p. 466 of this paper). *Diploastrea*, *thomorpha*, and *Oulastrea* are closely related genera. All are id corals that resemble in habit the genus *Orbicella*, and all have e confused with it. *Diploastrea* has more coarsely dentate and e perforate septa than *Cyathomorpha*, and it lacks the prominent, pali of *Cyathomorpha;* but the inner septal teeth of *Diploastrea* any instances simulate pali. For the present at least it is desirable eat each as a valid genus. According to Reuss (see p. 455 of this r), *Agathiphyllia* differs from *Cyathomorpha* in not having pali; efore, *Diploastrea* may be a synonym of *Agathiphyllia*.

efore discussing the species here referred to *Diploastrea*, mention be made of two species—*Brachyphyllia eckeli* [1] and *Brachyphyllia irregularis* [2] described by Duncan from St. Croix, Trinidad. The e, according to the figures, are fungid corals, and probably are referable to *Diploastrea*. The costae of the type-species of *Diploastrea* are either confluent or notched in the intercorallite areas. *Brachyphyllia*, until the type-species, *B. dormitzeri*, has been studied and

[1] Geol. Soc. London Quart. Journ., vol. 24, p. 13, pl. 2, fig. 4, 1867.
[2] Idem, p. 13, pl. 2, fig. 5.

described in more detail is an unidentifiable genus (see pp. 455, 45 this paper).

DIPLOASTREA HELIOPORA (Lamarck) Matthai.

Plate 134, figs. 1, 1*a*, 1*b*, 1*c*.

1816. *Astrea heliopora* LAMARCK, Hist. nat. Anim. sans Vert., vol. 2, p. 265.
1914. *Diploastrea heliopora* MATTHAI. Linn. Soc. London Trans., ser. 2, vol. 17, p. 72, pl. 20, figs. 7, 8; pl. 34, fig. 9.
1917. *Diploastrea heliopora* VAUGHAN, Carnegie Inst. Washington Pub. p. 143, pl. 59, figs. 5, 5*a*.

Figures 1, 1*a*, 1*b*, 1*c*, plate 134, are intended to illustrate the ge characters of the genotype. Plate 134, figure 1, is a natural size of the calices; figure 1*b* is a view of the calices enlarged four ti These figures illustrate the imperfect, synapticulate wall as seen above, the dentate septal margins, and the trabecular columella. should be noted here that the septal margins are not so prominen are they so coarsely dentate in all specimens. Plate 134, figur illustrates the costae of the edge of the lower part of the cora four times enlarged, and shows that the common wall originally is apticulate and perforate. Plate 134, figure 1*c*, is a longitudinal se of the corallites, four times natural size, to illustrate the interru corallited walls, the perforate character of the septa, and the sy ticulae and dissepiments on the septal faces.

Geographic distribution.—*Diploastrea heliopora* is found on living coral reefs of the Indo-Pacific from the east coast of A French Somaliland, eastward at least as far as the Fiji Islands. specimen here figured is from Djibouti, French Somaliland, coll by Dr. Charles Gravier.

DIPLOASTREA CRASSOLAMELLATA (Duncan) Vaughan.

Plate 135, figs. 1, 2, 3, 4, 4*a*, 5, 5*a*, 5*b*; plate 136, figs. 1, 1*a*, 1*b*; plate 137, figs. 2 4, 4*a*, 5.

1863. *Astraea crassolamellata* DUNCAN, Geol. Soc. London Quart. Journ., pp. 412–417, pl. 13, figs. 1–7.
1866. *Heliastraea crassolamellata* DUCHASSAING and MICHELOTTI, Sup. Antilles, p. 86 (of reprint).
1857. *Heliastraea crassolamellata* DUNCAN, Geol. Soc. London Quart. vol. 24, p. 24.
1870. *Heliastraea crassolamellata* DUCHASSAING, Rev. Zooph. Antilles, p.
1902. *Orbicella crassolamellata* and *Brachyphyllia* sp. VAUGHAN, Geol. Soc. Quart. Journ., vol. 57, p. 497.

The following are Duncan's original descriptions of the g characters of this species and of the typical form, and his synop the seven varieties into which he subdivided it:

General description.—"A group of forms from the Marl pr the following structural characteristics: Corallum very massiv large, with an irregular upper surface, which is convex in some

nost flat in others, and more or less largely gibbous in all: inter-
licular groove very decided. Corallites usually very large, and
ver very small. Wall very delicate and indistinct; costae small;
lumella large. Septa variable in cyclical arrangement, the larger
cessively developed at the wall and linear within. Endotheca
undant, but not in excess, vesicular. Exotheca not well devel-
ed, but decided and plentiful. Calices invariably found as casts.
pressions prove them to have been shallow. Coenenchyma well
veloped.

These characters, common to many forms, are more or less varied
intensity in different specimens. The septal number varies in
ividuals of the same corallum, in one series of forms to a remarka-
extent, although the corallites thus differing are nearly equal
liameter, and are nearly, if not quite, as advanced in development.
other forms it is fixed to four cycles in six systems; whilst in
ie there are three cycles in some systems, and only two in others,
corallum being large.

The form which I consider typical of the species has four perfect
es in six systems; but in some corallites the rudimentary sixth
seventh orders of a fifth cycle exist. The specific character-
s—the thick and great development of the septal laminae at
r wall end, and the more or less linear, but entire, conditions of
r internal parts—are seen in all these forms, in the primary,
ndary, and tertiary septa, according to the relative septal arrange-
ts. In some corallites with a low septal number, the primary
a alone are thus characterized; and as the higher cycles are
, so the secondary and tertiary septa become enlarged and resem-
the primary. The septa of the higher orders are either linear
ughout or slightly enlarged at the wall; and as they approach
tertiary or quaternary, as the case may be, they are seen to
me more equal to them in size. In examining these forms
l-ance must be made for their fossil condition; and attention
be given, in examining transverse sections of corallites, that
are quite at right angles to the corallite, for any obliquity will,
urse, diminish the peculiar spear-shape or mace-shape of the
p, and render them more like a paddle, or a leaf with the stalk
t hed.

he tendency of the higher orders of septa to become linear
r ghout, or to be less decidedly large at one end and thin else-
he—that is, more or less uniformly thick, but in a less degree
a is usual at the wall—is seen throughout the species; and in a
ig tic variety, where the fully developed corallites have 12 or 14
p in every system, the whole of the septa are less decidedly
ic at the wall, and are either more or less so throughout, or present
e ual form of the septa in a modified degree.

"This species is found throughout the great Marl formation, ... presents every variety of siliceous fossilization, from that cha... terized by silicification of the sclerenchyma and infiltration of ... interspaces by granular carbonate of lime, to that where all is silic... and capable of polish. Destructive silicification almost invari... exists in a greater or less degree; and as the sections preserved ... made, as a rule, for ornament or amusement, I have seldom ... accurately transverse and longitudinal views of the corallites.

"All the specimens, with the specific peculiarities mentioned, ... be ranged in several groups; that which contains the detailed ... acters in their greatest intensity, generally, may be considered ... typical form.

"*a. Astraea crassolamellata*, typical form.

"Corallum large, irregularly convex above. Corallites tall, l... crowded here and there, but not so much so higher up or at the ... face. Calices circular, but more or less elliptical when on an irregul... of the surface; very large, and separated from each other by ... marked, furrow-shaped, polygonal tracts; tracts marked by ... elevations and by granules.[1] Calices crateriform, not much ele... above the surface. Wall thin, and rendered insignificant by ... great development of the septa at the margin. Fossa not ... Costae numerous, and, considering the diameter of the septa a ... wall, very small; they project but little, and are, as a rule, ... nately large and small, not dentate, and often incline one to the ... at their free edge. The larger costae present regular enlarge... where the cross-tissue (dissepiments) of the exotheca joins ... when there are more than four cycles of septa, the smaller ... are irregular as regards their appearance and development. ... mella large, of lax laminae, parietal; it does not project much ... bottom of the fossa, and occupies a large space in the cor... Septa numerous, generally characterized by great enlargement ... wall, and linear appearance in the rest of their course, the l... orders being nearly linear at the wall also. The number of ... varies with the stage of development of the corallite.

Analysis of the species.

	Intercalicular furrow.	Septa.	Cycles.	Diame... of corall...
a. Astraea crassolamellata (type).	Well marked....	Very thick at wall..	4, in some 5..	19 to 20 m...
b. ——var. *magnetica*.....	.....do.....	.....do.....	4.....	12.7 mm.
c. ——var. *pulchella*.....	Less well marked	.....do.....	Variable	8 to 12.7 m...
d. ——var. *nobilis*.....	.....do.....	Very large at wall...	.....do.....	Variable.
e. ——var. *minor*.....	.....do.....	Very thick at wall..	2 and 3.....	Small, va... le.
f. —— var. *nugenti*.....	Less marked....	.....do.....	.....do.....	Do.
g. ——var. *magnifica*.....	Well marked....	Less thick, more linear.	4 to 6.....	8 to 25 ... an... more.

[1] As none of the specimens exhibit, perfect calices many of these characters have, of necessity, ... taken from casts.

"In young corallites there are six systems of three cycles. As owth proceeds the other orders of the fourth and sometimes of the h cycle are gradually added. Some systems are defective in tain orders, while others possess them. The largest corallites ve four perfect cycles, and a fifth in two or three systems; the th order being usually wanting. It is difficult, in the larger allites, to distinguish the systems on account of the resemblance he primary, secondary, and tertiary septa to each other.

"The primary septa are very thick externally, but delicate and ar elsewhere; the linear part joins the rest suddenly, like the f of a big-headed spear; at the junction the thick corners of the rgement give off a lateral spine, like a piece of endotheca; near costal end of the septa there are delicate lateral spines. The e between the sets of lateral spines is more or less square. The ndary septa are very like the primary.

"When there are more orders in the system than five—that is, n there are six, seven, eight, and nine—the tertiary septa equal primary and secondary, the blunt end terminating in the linear ion a little nearer the wall. When there are four cycles, the ary septa are smaller than the primary and secondary; and when e are only three cycles, as in young corallites, the tertiary septa linear throughout. The quaternary septa are linear and very tly developed; when there are more septa than those of the fourth e, the quaternary resemble small tertiary septa. The remaining are very small and linear, and reach a very little way from the ; they are apt to curve towards the septa nearest them. In ining the shape of the septa in this and in all the allied forms, cular attention must be paid that the section is quite transverse, y obliquity will more or less alter the shape of the larger end. s regards the endotheca, the dissepiments are frequent and te, and not very much developed. The exotheca is tolerably developed, but not in proportion to the size of the corallites. issepiments form square cells. The free surface between the e and calices has a few granules. Increase by extracalicular ation.

" arl formation of Antigua. Coll. Geol. Soc.

"*Measurements.*—Diameter of the calices in six specimens $\frac{3}{4}$ inch m.], in seven others $\frac{4}{5}$ inch [20 mm.], and in some from $\frac{1}{2}$ to $\frac{1}{4}$ 12.5 to 6.25 mm.]. The elliptical calices (situated on the sides corallum) are about $1\frac{1}{10}$ inch [27.5 mm.] in longest diameter. reatest thickness of the septa at the wall is $\frac{1}{10}$ inch [2.5 mm.]. ella $\frac{1}{5}$ inch [5 mm.] in diameter."

It is obvious that Duncan had no really good specimens on which e his original description of this species. I was fortunate in ing more than 60 specimens in Antigua, and have selected 14

of these as the basis of the following notes. Of Duncan's varie it seems to me that *magnetica*, *pulchella*, and *nobilis* should be c bined with the typical form of the species; that his varieties *m* and *nugenti* should be combined under one name, *nugenti*, prefe by me as it is desirable to preserve the record of the part D Nugent played in making known the fossil corals of Antigua; and variety *magnificea* should be retained without any important cha

DIPLOASTREA CRASSOLAMELLATA (Duncan) Vaughan, typical.

Plate 135, figs. 1, 2, 3, 4, 4*a*, 5, 5*a*, 5*b*; plate 136, figs. 1, 1*a*, 1*b*; plate 137, figs. 1, 4, 4*a*, 5.

Plate 135, figure 1, illustrates, natural size, a polished surface typical specimen in Duncan's original sense; and plate 135, figu illustrates natural size, a polished surface of Duncan's variety *no* Duncan did not recognize that the septa in such specimens ar perforate and that synapticulae are abundant. These two fi re will serve to validate the identifications here made, as referen Duncan's original figures will show.

As I collected a series of specimens ranging from a solitary co to a fully developed corallum, the development of the corallum wi be described.

Specimen No. 1.—The only solitary corallite I collected (pl. 3 fig. 3) is inversely sub-conical in shape, the apex broken. 28.5 mm. tall, and is 16 by 18 mm. in maximum diameter. Th older calice was damaged and a smaller calice has formed abo th older. On the outer surface is an incomplete, finely striate pell la epitheca; subequal or alternately larger and smaller, more o les interrupted, beaded costae are seen in the areas not covered b th epitheca. The costal ends are joined by synapticulae, be ee which are perforations. The wall originally is synaptic at Septal margins coarsely beaded. Primary and secondary pt solid for the most part; tertiaries more perforate; quaternari de cidedly perforate. Columella well developed; surface co sel papillary; fossa shallow. As the structural characters of this pe men are essentially identical for all other typical specimen th species, descriptions of the epitheca, costae, and intercostal sy pt culae need not be repeated.

Specimen No. 2.—In this specimen the primary corallite has iv rise to one lateral bud (pl. 135, figs. 4, 4*a*), between which a th parent corallite is a slightly depressed intercorallite area. Di et of parent corallite, 24 mm. Septo-costae more or less co ue and continuous, interrupted with perforations, joined to one a th by synapticulae; margins coarsely, rather irregularly beaded.

Specimen No. 3.—There are seven corallites, separated by wid intercorallite grooves, in this specimen. Five corallites are ov

plate 135, figure 5. The lesser diameter of the three larger coral-
s is 19 mm.; the greater diameter ranges from 21 to about 23 mm.
e calices of this specimen are shallow. In the calice represented
plate 135, figure 5*b*, it will be seen that the primary and secondary
ta are subequal and are thicker than the members of the higher
les. There are about 86 septa in this calice—that is, there are 4
nplete cycles and 38 quinaries. The primaries and secondaries
solid for the most part; the tertiaries are somewhat thinner and
r the columella they are represented by only partially fused
ttal tabeculae. The quaternaries are thinner and more perforate
n the tertiaries, to which they fuse by their inner ends rather
r the columella. The quinary septa are still thinner and very
orate; they tend to fuse to the sides of the included quaternary.
the inner part of the largest septa are indefinite lobes or teeth,
e of which simulate partially developed paliform lobes. Synap-
lae are greatly developed, between both the costae and the septa;
there are endothecal dissepiments.

pecimen No. 4.—This specimen is composed of seven corrallites,
e 137, figure 1. It differs from specimen No. 3 principally by
ng deeper calices and on some of the large septa there are fairly
-developed paliform lobes.

ecimen No. 5.—Plate 136, figures 1, 1*b*, are two views, natural
of a specimen that is essentially typical variety *nobilis* of Duncan.
ffers from the typical form of the species by having somewhat
ler corrallites and consequently less numerous septa. Specimens
ging the slight gap between specimens Nos. 4 and 5 might be
ibed, but to do so seems unnecessary.

e foregoing descriptions apply to the typical form of the species;
variants will now be considered.

ecimen No. 6.—Plate 137, figure 3, represents a calice and inter
lar areas in a specimen that differs from specimen No. 3 chiefly
he nonexsert calicular margins.

ecimen No. 7.—The calices represented by plate 137, figures 4, 4*a*,
f a specimen that practically intergrades with specimen No. 6.
calices illustrated are smaller and the septo-costae coarser than
ecimen No. 6. Plate 137, figure 5, illustrates a closely similar
men from the base of the Chattahoochee formation, on Flint
, about 4 miles below Bainbridge, Georgia. The calices of the
ridge specimens are excavated, thereby differing from specimen
.

Specimen No. 8.—This specimen, plate 137, figure 2, has corallites
are more prominent and more isolated than in the other
ens described, and the costae on the free corallite limbs are
subequal.

Localities and geologic occurrence.—Island of Antigua, in the Ant
formation, at stations 6854, Rifle Butts; 6856, Friar's hill; 6
Willoughby Bay; 6888, one-half mile north of McKinnon's
collected by T. W. Vaughan. Previously collected by Robert T.
and by J. W. Spencer, in addition to the material originally stu
by Duncan.

Island of Porto Rico, Lares road, associated with corals, repres
ing the Pepino formation of Hill, collected by Bela Hubbard o
New York Academy Scientific Survey of Porto Rico.

Cuba, station 3481, Rio Canapu, Manassas trail, collecte
Arthur C. Spencer. Station 7506 west side of Ocujal Spring,
Guantanamo, Cuba, altitude between 200 and 250 feet, at co
with underlying conglomerate, collected by O. E. Meinzer.
ments from station 7522, Mogote Peak, one-half mile east of
boundary of United States Naval Reservation, Guantanamo,
tion about 375 feet, a. t., collected by O. E. Meinzer, probably
be referred to variety *magnifica* (Duncan).

Georgia station 3381, 4 miles below Bainbridge, Flint Riv
the base of the Chattahoochee formation, collected by T. W. Vau

Panama, station 6587, Tonosi River, collected by D. F.
Donald. A poorly preserved specimen from this locality
referable to this species.

This is stratigraphically one of the most important coral spec
the American Oligocene, for it seems to occupy almost the ide
horizon everywhere it has as yet been found. Its stratigr
position, as at present known, is middle Oligocene; but the poss
of some specimens being upper Eocene needs to be borne in min
page 206).

DIPLOASTREA CRASSOLAMELLATA var. MAGNIFICA (Duncan) Vaughan.

Plate 138, figs. 1, 2, 2*a*.

1863. *Astraea crassolamellata* var. *magnifica* DUNCAN, Geol. Soc. London,
Journ., vol. 19, p. 417, pl. 13, fig. 3.

The following is Duncan's original description: "In the s
corallites of this variety the spear-shaped septa are seen; but
larger, where there are from twelve to fourteen septa in a syste
primary, secondary, and tertiary orders are nearly equal i
They have lost the extreme relative thickness between their ex
ties, and, although still very thin at the columella, they are not
developed at the wall. In some corallites the septa, in tra
view, are not straight, but form curving radii; and in all, the
which the septa bear to the interseptal spaces and to the wall
much exaggerated.

"Corallites circular in transverse section; they vary much in
ter, and are now and then crowded, but generally have much

yma between them. The diameters of five corallites are as follows: inch [21 mm.], $\frac{2}{3}$ inch [17 mm.], 1 inch [25 mm.], $1\frac{1}{10}$ inches [27.5 mm.] inch [12.5 mm.]. Walls very indistinct. Costae small, and appear- g to be appended to all the septa. Exotheca is present and connects e costae. Septa numerous, especially in large corallites, where the cles, which are small and rudimentary in the lesser, become well veloped. In the smallest corallites there are six systems of four cles, the fourth and eighth orders being very small. In medium- ed corallites there are six systems, four cycles in five systems, and the sixth there are the rudimentary sixth, seventh, and eighth lers. The first, second, and third orders are nearly equal in size. the largest there are six systems, and from twelve to fourteen ta in every system. Lateral teeth exist on all the primary septa the place of greatest width. The higher orders in every system very linear. Endotheca abundant, but not in excess. Columella ge, well developed, and spongy. Coenenchyma formed of cells duced by the costae and the exothecal dissepiments."

Except that Duncan failed to recognize that this is a fungid coral description is good.

am introducing on plate 138 figures of two specimens of this iety, one specimen from Antigua (fig. 1); the other from Flint er, near Bainbridge, Georgia, (figs. 2, 2*a*).

ocalities and geologic occurrence.—Antigua, in the Antigua forma- n, station 6881, Willoughby Bay, collected by T. W. Vaughan.

orto Rico, Lares road, associated with corals representing the ino formation of Hill, collected by Bela Hubbard of the New k Academy Scientific Survey of Porto Rico.

uba, station 7522, collected by O. E. Meinzer. It was stated on 476, that the fragments obtained by Mr. Meinzer on Mogote Peak Guantanamo seem referable to this variety.

eorgia, station 3381, 4 miles below Bainbridge, Flint River, in base of the Chattahoochee formation, collected by T. W. ghan.

is variety has the same stratigraphic significance as the typical of the species.

DIPLOASTREA CRASSOLAMELLATA var. NUGENTI (Duncan) Vaughan.

Plate 138, fig. 3, 3*a*.

363. *Astraea crassolamellata* var. *minor* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, pp. 414, 416, pl. 13, fig. 6.

363. *Astraea crassolamellata* var. *nugenti* DUNCAN, Geol. Soc., London Quart. Journ., vol. 19, pp. 414, 416, pl. 13, fig. 5.

Duncan's original description of variety *nugenti* is as follows: "The specimen upon which this variety is founded has no calices

but the transverse views of the corallites are very distinct. Co l- lites one-third inch [8.3 mm.] in diameter, not crowded. Septa in six systems, two cycles in four systems and three in the other t o. The tertiary orders are small, and often join the secondary near ne columella. The primary septa are square and large at the wall, nd not very linear, but staff-shaped within; their width at the margi is one-fifteenth [1.7 mm.] inch. The secondary septa are very m ch smaller and thinner than the primary, but nearly as large when he tertiary orders are present. Costae wide apart. Exothecal ells scalariform, wider than high; from one-thirtieth to one-sixt th [0.8 to 0.4 mm.] inch high, and one-fifteenth inch [1.7 mm.] lg. Endotheca abundant.

"This form has squarer headed septa, longer exothecal cells, co ae wider apart, and a lower septal number than many of the form of the species; and differs from the forms with three more or less inc m- plete septal cycles in the greater thickness of the inner part of he septal laminae, the broad exothecal cells, and in the disposition o he tertiary septa to join the secondary."

The original description of var. *minor* is as follows:

"Corallites tall, slender, crowded, distinct; walls circular, not t ck. Calices circular, somewhat variable in size; the largest is three-te ths inch [7.5 mm.] in diameter. The larger septa are spear-shaped th smaller linear; they are in six systems of two cycles; rarely three c le in two systems in some corallites. Primary septa much larger an the secondary, but nearly equaling them when there is a third c le. Columella large.

"The alternate large and small, spear-shaped and linear sept a very well seen in this form. The same details as in this form ar found in several specimens with larger corallites."

It seems to me that varieties *nugenti* and *minor* should not be pa rated, and I am using *nugenti* as the varietal name. This vari y is principally characterized by its small (diameter about 7 mm.) an relatively distant calices. The specimen represented by plate 38 figures 3, 3*a*, apparently has more compact structures than speci en more typical of the species. The compact appearance I believe s i large part due to secondary mineral changes, and to the surface h ing been worn, for some septal perforations are recognizable and s ap ticulae are distinct. An unfigured specimen referred to var. *n ent* has perforate corallite walls and perforate septa, but the sept of worn lateral corallite are mostly solid. As it is usual for the sk eta structures of stunted corals to be denser than those of spec en living under more favorable conditions, it is probable that *nug ti* i only a vegetational variant of typical *D. crassolamellata*.

Localities and geologic occurrence.—Antigua, in the Antigu for mation at station 6881, Willoughby Bay (figured specimen), and 854 Rifle Butts, collected by T. W. Vaughan.

MADREPORARIA PERFORATA.

Family EUPSAMMIIDAE Milne Edwards and Haime.

Genus BALANOPHYLLIA Searles Wood.

1844. *Balanophyllia* Searles Wood, Ann. and Mag. Nat. Hist., vol. 13, p. 11.

Type-species.—*Balanophyllia calyculus* Searles Wood.

BALANOPHYLLIA PITTIERI, new species.

Plate 139, figs. 1, 1*a*, 1*b*, 2, 2*a*.

Corallum compressed-cornute in form. The smaller of the two types is 32 mm. long; greater diameter of calice, 4 mm.; lesser ameter of calice, 8.5 mm. (See pl. 139, figs. 1, 1*a*, 1*b*.) The larger ype has both the lower and upper ends broken. It is 41 mm. long; ater diameter of lower end, 9.5 mm.; lesser diameter, about 7 mm.; ater diameter of upper end, 20.5 mm.; lesser diameter, 13 mm. e pl. 139, figs. 2, 2*a*.)

Wall perforate between the costae, less perforate along the costae; comes secondarily thickened; the interseptal loculi near the base are ost solidly filled. There is some pellicular epitheca, which may ch to within 3 mm. of the calicular edge. Costae relatively wide, h narrow interspaces, subequal, every fourth may be somewhat more prominent where there are four cycles of septa; in general costae corresponding to the primary and secondary septa are the re conspicuous. In profile they are flat or faintly carinate; about ee ill-defined rows of granulations along them, or there are irregu- y scattered granulations; where the costae are slightly carinate median row is the more prominent.

epta with typical balanophylliid arrangement; in the smaller co- e four complete cycles and a few quinaries; in the larger cotype, r complete cycles and many quinaries, a total of about 78 septa. iform lobes appear well developed before the secondaries.

olumella well developed, elongate, vesicular, protuberant in the tom of the calice.

ocality and geologic occurrence.—Costa Rica, "Colline en démoli- n," Limon, No. 618, H. Pittier collection. Station 6249, Hospital nt, Bocas del Toro, collected by D. F. MacDonald. The horizon bout that of the Bowden marl.

'otypes.—Nos. 325014, U.S.N.M.

Family ACROPORIDAE Verrill.

Genus ACROPORA Oken.

1815. *Acropora* Oken (part), Lehrb. Naturg., Th. 3, Abth. 1, p. 66.
1902. *Acropora* Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, pp. 164, 208 (with synonymy).
1918. *Acropora* Vaughan, Carnegie Inst. Washington Pub. 213, p. 159.

ype-species.—*Millepora muricata* Linnaeus, s. s. = *Madrepora cervi- is* Lamarck.

ACROPORA PANAMENSIS, new species.

Plate 141, figs. 1, 1*a*, 1*b*, 2.

Corallum composed of rather thick branches, apices bluntish, or at least not acuminate. The specimen (the holotype) represented by plate 141, figure 1, is 58 mm. long; the diameter of its lower end is 15 mm.; upper end broken, compressed, 20 mm. wide, lesser diameter of fracture 8 mm.; diameter of end of a new lateral branch not yet fully formed about 4.5 mm. The diameter of the lower end of the specimen (paratype) represented by plate 141, figure 2, is 15 mm.

As the axial corallites are broken their characters are not known. Radial corallites of two kinds, protuberant and immersed or submmersed. Protuberant corallites ascending, appressed, tubular, slightly compressed. Length as much as 4 mm., about 2.5 mm. probably an average; all intermediate lengths down to the immersed corallites. Greater diameter ranges from 2 up to 3.5 mm.; lesser diameter from 2 to 2.5 mm. Distance apart in vertical rows or spiral from 1 to 2.5 mm.; in horizontal plane, from 1.5 to 3 mm. Lower wall better developed than the upper, texture rather loose, of moderate thickness, outside strongly costulate with synapticulae clearly visible between the costules; upper edge not rounded or incurved in the cotyes. Upper wall short but traceable. Apertures with margins which slope downward and outward from the upper wall or they are short laboratiform no nariform or dimidiate apertures were observed. Two well-developed cycles of septa, primaries larger than the secondaries, upper directive more prominent than the lower; in some calices apparently there may be a few tertiaries. Immersed and subimmersed corallites smaller and with less developed septa than the protuberant corallites.

Coenenchyma porous, granulate, reticulate, costulate, and somewhat flaky.

Locality and geologic occurrence.—Canal Zone, station 2024*b*, crossing of Panama Railroad over Rio Agua Sabud, between Bohio Ridge and New Frijoles, in the Emperador limestone, collected by T. W. Vaughan and D. F. MacDonald.

Antigua, station 6854, Rifle Butts, in the Antigua formation, collected by T. W. Vaughan.

Type.—No. 325042*a*, U.S.N.M.

Paratype.—No. 325042*b*, U.S.N.M.

This species belongs to the subgenus to which Brook applied the name *Eumadrepora*, that is, *Acropora* s. s., but it is not closely related to *Acropora muricata* (Linnaeus) and its relatives, *A. prolifera* (Lamarck) and *A. palmata* (Lamarck), of the Floridian and West Indian region.

ACROPORA SALUDENSIS, new species.

Plate 141, figs. 3, 3*a*, 4, 4*a*.

Corallum composed of relatively slender branches. The dimensions of the two cotypes which are branch segments are as follows:

Dimensions of branches of Acropora saludensis.

Branch No.	Length.	Diameter of lower end.	Diameter of upper end.
	mm.	*mm.*	*mm.*
	28	10 by 11	9 by 11
	34	10.5 by 12	8 by 11.5

The diameters are given for the stem proper, exclusive of the corallite protuberances. The relatively greater width of the upper end of No. 2 is due to its apparently being at the base of a bifurcation. The form of the corallum was probably arborescent.

The characters of the axial corallites not distinguishable in the cotypes. The radial corallites, although not all of equal size, are nearly all protuberant, a few subimmersed but no immersed corallites were seen; however, immersed corallites might be present on the basal part of the corallum. The form is ascending appressed tubular; length measured along lower side, 2.5 to 3.5 mm.; lesser diameter 1.5 to 2.5 mm.; greater diameter 1.75 to 2.5 mm.; lateral compression relatively slight but apparent. Lower and side walls well developed, thick, rather dense, outer surface usually strongly costulate; upper edge of lower wall more or less rounded, somewhat lacinate in some corallites. Upper wall only slightly protuberant or obsolete. Apertures nariform or dimidiate. Primary septa well developed; secondaries recognizable in many calices, appear to be usually present.

Coenenchyma relatively dense, surface closely beset with coarse, somewhat elongate, more or less vermiculate granules, no well-defined costules.

Localities and geologic occurrence.—Canal Zone, Emperador limestone, at station 6024*b*, crossing of Panama Railroad over Rio Agua Salud between Bohio Ridge and New Frijoles (cotypes); and at station 6016, quarry, Empire, collected by T. W. Vaughan and J. F. MacDonald.

Antigua, station 6854, Rifle Butts, in the Antigua formation, collected by T. W. Vaughan.

Cotypes.—No. 325043, U.S.N.M. (2 specimens.)

This species belong in the same group of *Acropora* as *A. squarrosa* (Ehrenberg), *A. rosaria* (Dana), and *A. murrayensis* Vaughan,[1] and is referrable to the subgenus *Rhabdocyathus* of Brook.

ACROPORA MURICATA (Linnaeus).

1758. *Millepora muricata* LINNAEUS (*part*), Syst., Nat., ed. 10, p. 792.
1767. *Madrepora muricata* LINNAEUS (*part*), Syst., Nat., ed. 12, p. 1279.

[1] Vaughan, T. W., Some shoal-water corals from Murray Island (Australia), Cocos-Keeling, and Fanning Islands, Carnegie Institution, Washington Pub. 213, pp. 183–184, 1918.

1893. *Madrepora muricata* forma *cervicornis* Brook, Brit. Mus. (Nat. Hist.) t. Madrep. corals, gen. Madrepora, p. 27.

1900. *Madrepora cervicornis* Gregory, Ann. and Mag. Nat. Hist., ser. 7, vo. 6, p. 30.

1901. *Isopora muricata* s. s. Vaughan, U. S. Fish. Com. Bull. for 1900, vo. 2, p. 313, pl. 21, pl. 22, fig. 2.

1902. *Acropora muricata* var. *cervicornis* Verrill, Conn. Acad. Arts and i. Trans., vol. 11, p. 167.

1903. *Madrepora muricata* Duerden (*part*), Nat. Acad. Sci. Mem., vol. 8, p. 3. pls. 1 to 3, figs. 1 to 27.

1915. *Acropora cervicornis* Vaughan, Washington Acad. Sci. Journ., vol 5, p. 597.

1916. *Acropora cervicornis* Vaughan, Carnegie Inst. Washington Yearbook o. 14, p. 228.

The nomenclature of the living West Indian and Floridian spe es of *Acropora* is, in some respects, amusing. Brook in 1893, a er studying the considerable collections in the British Museum of Nat al History, reached the conclusion that the three previously rec g-nized species from Florida and the West Indies, *A. cervicor is A. prolifera*, and *A. palmata*, really represented only forms of ne species, to which he applied the specific name *muricata* of Linna s. Gregory in 1895 [1] adopted the opinion of Brook, but in 1899 e visited the West Indian coral reefs and decided that all three suppo d species were valid (see reference for 1900 in the foregoing synonyn). I studied a large suite of specimens and concurred with Bro s (reference for 1901 in synonymy), and Verrill in his paper for 1 02 followed the same course. From 1908 to 1915 (inclusive) I d extensive field experience with the living coral reefs of Flor a, the Bahamas, and some of the Lesser Antilles, and am convin d that Gregory's opinion, based on field acquaintance with these co s, is correct. Very rarely indeed does one find a specimen that can ot be instantly referred to its proper species. In some of my pa rs on the ecology and growth rate of Floridian and Bahaman cor s,[2] I have referred to this species as *Acropora cervicornis*, bec se *cervicornis* is a rather generally known name for it.

Localities and geologic occurrence.—Pleistocene at stations 5 0, Mount Hope, and 6554, mud flat, 1 foot above ordinary high-tide l el, Colon, Canal Zone; station 6251, Monkey Point, Costa R a, collected by D. F. MacDonald; and Moin Hill, Limon, Costa R a, "Niveau A.," collection of H. Pittier.

This species is general in the West Indian and eastern Cen al American Pleistocene reefs, where they were not exposed to ne beat of the heavy surf. Recent; eastern Central America, the V st Indies, and Florida.

[1] Geol. Soc. London Quart. Journ., vol. 51, p. 281, 1895.

[2] Mostly in Yearbooks Nos. 9 to 14 of the Carnegie Institution of Washington.

ACROPORA PALMATA (Lamarck).

1816. *Madrepora palmata* LAMARCK, Hist. nat. Anim. sans Vert., vol. 2, p. 279.
1893. *Madrepora muricata* forma *palmata* BROOK, Brit. Mus. (Nat. Hist.) Cat. Madrep. corals, gen. Madrepora, p. 25.
1900. *Madrepora palmata* GREGORY, Ann. and Mag. Nat. Hist., ser. 7, vol. 6, p. 29.
1901. *Isopora muricata* forma *palmata* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 313, pls. 26 and 27.
1902. *Acropora muricata* var. *palmata* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 166.
1915. *Acropora palmata* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, pp. 597, 598.
1916. *Acropora palmata* VAUGHAN, Nat. Acad. Sci. Proc., vol. 2, pp. 95, 100.
1916. *Acropora palmata* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, pp. 227, 228, 229, 230.

Localities and geologic occurrence.—Costa Rica, Pleistocene at ation 6251, Monkey Point, collected by D. F. MacDonald. Also f the slightly elevated reefs around Colon Bay.

Acropora palmata is of general occurrence in the elevated Pleistoe coral reefs of eastern Central America and the West Indies; d is present on the living reefs of the same region and in Florida. l places, as in the Bahamas, it is one of the most important reefming corals, its strong skeleton enabling it to withstand the poundi of breakers.

Genus ASTREOPORA de Blainville.

1896. *Astraeopora* BERNARD, Brit. Mus. Cat. Madreporaria, vol. 2, pp. 77-99.
1918. *Astreopora* VAUGHAN, Carnegie Inst. Washington Pub. 213, p. 145.

Type-species.—*Astrea myriophthalma* Lamarck.

ASTREOPORA GOETHALSI, new species.

Plate 140, figs. 3, 4, 4*a*.

Corallum composed of rather large, subterete, subelliptical, or ch compressed branches. The following are measurements of r broken branches:

Measurements of branches of Astreopora goethalsi.

Branch No.	Length.	Diameters of lower end.	Diameters of upper end.
	mm.	*mm.*	*mm.*
1	85	27 by 56	26 by 71 [1]
2	134	42 by 52	28 by 55
3	154	32 by 44	28 by 65
4	186	16 (thick)	25 by 94

[1] Width at bifurcation 22 mm. below upper end.

alices subcircular or more or less distorted. Diameter ranges fr 1 mm. in young, to 2 mm. in large calices, usual diameter from 1. to 2 mm. Distance apart from 1 to 1.5 mm. Calicular rims

slightly elevated, not quite 0.5 mm., due to the projection of the corallite walls beyond the coenenchymal surface. Distinct costae correspond to most, if not all, of the septa; irregular in size, but those corresponding to the primaries are usually the larger.

Septa in two complete cycles, with a variable number of tertiaries. Primaries usually well differentiated from the other septa, thicker, longer, and somewhat taller; in many calices a larger primary marks the plane of symmetry: secondaries and tertiaries small.

Columella poorly developed, in some calices a false columella formed by the fusion of the inner end of the primary septa is recognizable.

Coenenchyma with a flattish surface between corallites, verticulately costate, with perforations between the costae in areas not covered by glassy-looking basal deposit, which in the cross-sections of some branches is solid, in the cross-sections of others there are platforms one above another.

Locality and geologic occurrence.—Canal Zone, stations 6015 and 6016, in the Emperador limestone, quarries, in the town of Empire, collected by T. W. Vaughan and D. F. MacDonald. The same or a very closely related species occurs at stations 3381 and 3383, respectively, 4 and 7 miles below Bainbridge, Georgia, in the base of the Chattahoochee formation, collected by T. W. Vaughan.

Cotypes.—No. 325036, U.S.N.M. (2 specimens).

Paratypes.—No. 325043, U.S.N.M. (4 specimens).

ASTREOPORA ANTIGUENSIS, new species.

Plate 139, figs. 3, 3*a*; plate 140, fig. 1.

Corallum forming large thick branches that may be more or less palmate. Plate 139, figure 3, represents a branch one-half natural size.

The calices are moderately deep, more or less irregular in outline, often subelliptical, the diameter ranges from 2 to 4 mm. Their margins elevated about 1 mm., and are distant from one another from 1.5 to 2.5 mm. Somewhat swollen around the base. Inner limbs of corallites more or less distinctly costate.

The septal arrangement appears often to be irregular, sometimes two complete cycles and an incomplete third, in many calices the third cycle is complete, and occasionally a few members of the fourth cycle may be present. The absence of the smallest septa undoubtedly is often due to their destruction in fossilization.

Columella very poorly developed, in fact there may be none at all.

Coenenchymal surface usually formed by a compact basal deposit, but in places perforations may be recognized between costae.

Locality and geologic occurrence.—Antigua, Morris Looby's Hill, in e Antigua formation, collected by R. T. Hill.

Georgia, station No. 3381, Russell Spring, Flint River, Decatur unty, Georgia, collected by T. W. Vaughan, in the base of the attahoochee formation.

Canal Zone, station No. 6026, 2 miles south of Monte Lirio, col- ted by T. W. Vaughan and D. F. MacDonald in the Culebra mation.

Type.—Museum of Comparative Zoology.

Paratype.—No. 325609, U.S.N.M.; also other specimens.

Comparison of the specimens from near Bainbridge, Georgia, with smaller specimens from Antigua, fails to reveal any difference atever between the specimens; and no noteworthy difference is n between the other specimens and the best one from near Monte io.

ASTREOPORA PORTORICENSIS, new species.

Plate 140, figs. 2, 2*a*.

Corallum ramose, branches subcircular or elliptical in cross- tion. Length of type, 56 mm.; greater diameter of lower end, mm., lesser, 13 mm.; width of upper end (which is bifurcating) ut 30 mm.

Calices moderately deep, usually deformed, one diameter longer n the other. A small calice has a greater diameter of 1.7 mm., er, 1.3 mm.; a rather large calice has diameters measuring 2.3 1.6 mm., respectively. The distance apart of the calices varies m 1.3 to slightly more than 2 mm. Calicular margins scarcely ated; there is really no distinctly elevated rim.

Septa, in the larger calices, in three cycles, the last very small; r outer ends thick, the inner portions thin. Upper margins very tly exsert.

Columella, poorly developed.

Coenenchymal surface usually coated by basal deposit, but in es costae with intervening perforations are obvious.

Locality and geologic occurrence.—Porto Rico, station 3191, 4 miles of Lares, Pepino formation, collected by R. T. Hill.

Type.—No. 325306, U.S.N.M.

This species is very near *Astreopora antiguensis;* in fact, I am by no ns sure that they are really distinct. The type of *A. portoricensis* a smaller and less prominent calices; but some of the specimens of *A. antiguensis* from Bainbridge, Georgia, have small calices. The ical difference, therefore, consists in the low, nonprotuberant es of *A. portoricensis*, a difference which, according to the vailable material, is valid.

Genus ACTINACIS d'Orbigny.

1849. *Actinacis* d'Orbigny, Notes sur des Polyp. foss., p. 11.
1860. *Actinacis* Milne Edwards, Hist. nat. Corall., vol. 3, p. 170.

Type-species.—*Actinacis martiniana* d'Orbigny.

I have not been able to study the type-species of this genus, but judging from Reuss's figures of *A. martiniana* [1] it is probable that the corals here referred to are correctly determined.

Besides the species described here, there is another species of *Actinacis* in the West Indies Tertiary formations, namely, the coral from the Eocene St. Bartholomew limestone, to which Duncan applied the name *Astreopora panicea*.[2] It will be considered in another paper.

The species to which Duncan applied the names *Heliastraea exsculpta* [3] (not *Astraea exsculpta* Reuss [4]) and *Heliastraea cyathiformis*,[5] and which I made under the latter name, the type species of *Multicolumnastraea*,[6] deserves mention here. The intercorallite cones in Duncan's *Heliastraea cyathiformis* are more or less vermiculate and are joined one to another by synapticulae, between which there are openings. This species is very close to *Actinacis*, but the coarse columellar tubercles or pillars may warrant generic separation. The species, according to the stratigraphic data supplied by Mr. R. T. Hill, occurs in his Blue Mountain Series, of Cretaceous age, and in Catadupa beds, of Eocene age.[7] It seems to me that the Catadupa beds are probably of Cretaceous age, for they contain no species of corals in common with the Richmond and Cambridge formations, while two of the five species recorded from them are common to the Blue Mountain Cretaceous.

ACTINACIS ALABAMIENSIS (Vaughan).

Plate 149, figs. 3, 3*a*.

1900. *Turbinaria* (?) *alabamiensis* Vaughan, U. S. Geol. Survey Mon. 39, p. 94, pl. 23, figs. 1, 2, 3; pl. 24.

The type-specimen (Cat. No. 158482) and the paratypes (Cat. Nos. 158480 and 158481, U.S.N.M.) clearly belong to the genus *Actinacis*, to which I suggested they might belong in the original account of the species. The following is the original description:

"Corallum massive, the masses may be more than 20 cm. across and 7 cm. thick, upper surface apparently convex or concave.

[1] Beiträge zur Charakteristik der Kreideschichten in den ostalpen, K. K. Akad. Wiss. Wien. Math.-Naturw.-Cl., vol. 7, pl. 24, figs. 12–15, 1854.
[2] Geol. Soc. London Quart. Journ., vol. 29, p. 561, 1873.
[3] Idem, vol. 21, pp. 7, 8, 11, 1865.
[4] K. K. Akad. Wissens.h. Wien. Math.-Naturw. Cl., Denkshr. vol. 7, p. 114.
[5] Geol. Soc. London Quart. Journ., vol. 21, pp. 7, 8, pl. 1, figs. 1*a*, 1*b*, 1865.
[6] Mus. Comp. Zool. Bull., vol. 34, pp. 235–237, pl. 37, figs. 5, 6, 7; pl. 38, fig. 1, 1899.
[7] Vaughan, T. W., Mus. Comp. Zool., vol. 34, p. 231, 1899.

l appearance of the corallum is as if composed of superimposed
inae. Calices shallow (?), crowded; diameter, 1.5 mm.; distance
rt, quite constantly 1 mm. Coenenchyma, of superimposed
gularly perforate laminae. Wall, perforate. Septa, perforate, in
e complete cycles; 12 septa reach the columnella; the members
he third cycles usually fuse by pairs to the sides of an included
tum (the first and second cycles can not be distinguished from
other, and therefore it can not be known whether the septa
he third fuse to the sides of the first or second). Sides granulate.
i are probably present, but no detail could be made out. Columella
well developed, spongy.

Locality.—Salt Mountain, 6 miles south of Jackson, Alabama.

Geologic horizon.—'Coral limestone,' above Vicksburg beds."

I have not been able to decide positively whether this is an Acti-
s or a Turbinaria. It probably belongs to the latter genus."

he following is a description of a species of *Actinacis*, referred to
labamiensis, from Flint River, near Bainbridge, Georgia:

orallum forming large explanate masses, a foot or more across
70 to 75 mm. thick. The perpendicular section shows a thinly
ellate structure.

alices small, 1.3 to 1.5 mm. in diameter, usually separated by less
their own diameter of coenenchyma. The coenenchyma is
posed of flexuous, perforate, granulated costae, which are fused
a reticulum by abundant synapticulae. The calices are dis-
ly differentiated from the coenenchyma, but a definite wall is
poorly developed; where it is present, it appears to be due to
e of peripherally disposed synapticulae. The costae often lead
tly across the coenenchyma from one calice to the next, thus
ng the septa of adjacent calices.

pta slightly less in thickness than the interseptal loculi. The
l number is about 20, the third cycle as a rule is incomplete,
ged with reference to a plane of symmetry. The presence of a
tive plane and the grouping of the septa into pairs or groups of
s is characteristic. Pali occur at the junctions of the inner
of the septa—it seems that the full number is 12. The inter-
l loculi are conspicuously open; if any synapticulae are present,
e are rare.

Columella well developed, composed of septal processes.

Species of *Actinacis*, apparently the same as *A. alabamiensis*, was
ted by me in Antigua. It is represented by a small piece
m. long, 33 mm. wide, and 25 mm. in maximum thickness.
pper surface is nodose; calices from 1.25 to 1.5 mm. in diameter;
nchyma composed of a fine trabecular mesh work. This speci-
eems to me to belong to the same species as the specimens from
Bainbridge, Georgia, that I am identifying as *A. alabamiensis*.

Localities and geologic occurrence.—Alabama, Salt Mountain, 6 m south of Jackson, in the "coral limestone" above the top of Vicksburg group, collected by T. W. Vaughan (the type).

Georgia, station 3381 and 3383, on Flint River, respectively 4 ar miles below Bainbridge, in the base of the Chattahoochee format collected by T. W. Vaughan.

Antigua, West Indies, station 6854, Antigua formation at H Butts, collected by T. W. Vaughan.

This species is of a high order of importance in the correlatio American Oligocene deposits.

The septal arrangement in *A. alabamiensis* is similar to a of *Porites* in the presence of a plane of symmetry and the tend of the septa to fuse by their inner ends in pairs. The septa th selves, however, are very different, being lamellate, almost im forate, and sharply differentiated from the surrounding coenenchy

Professor Felix in his Anthozoen der Gosauschichten in e Ostalpen [1] has redescribed and figured *A. haueri* Reuss and *A. martiniana* d'Orbigny. He does not speak of the bilateral symm of the calices but both of his figures indicate such a condition, i each there are two opposite elongate septa that connect with c other through the columella. I take it, then, that the calic *A. martiniana* are bilaterally symmetrical with the septa gro not very definitely in two's, three's, four's, or five's on each si the median plane.

It seems probable that *Actinacis* may be intermediate in char between the families *Acroporidae* and *Poritidae*. These notes suggestions are made in the hope that some one with the req material may make a more careful study of the Cretaceous sp of the genus to determine the relations of those two families.

Family PORITIDAE Dana.

Genus GONIOPORA Quoy and Gaimard.

1833. *Goniopora* Quoy and Gaimard, Voyage de l'*Astrolabe*, Zool., vol. 4, 2

Type-species.—*Goniopora pedunculata* Quoy and Gaimard.

GONIOPORA HILLI, new species.

Plate 142, figs. 1, 1*a*.

Corallum composed of flattish plates, which may be more th 2 cm. wide and 4 cm. thick and appear to have grown in a su or zontal position.

The calices are polygonal, from 3 to 4 mm. in diameter, f m to 1.5 mm. deep, separated by walls from 0.75 to 1.25 mm. ic The walls are crossed by rather low costae, and in places there is on

[1] Palaeontographica, vol. 49, pp. 176–178, figs. 2, 3, 1903.

ercalicular reticulum, but it usually does not well up and form
ks, ridges, and crests between the calices.
epta of the normal gonioporid number and arrangement, outer
ts thick and subequal, all relatively narrow in their upper parts,
either fall steeply or slope to the level of the large columella
gle, which is joined by the primaries and secondaries and the ter-
ies fuse to the secondaries near it. Usually 3 or 4 teeth on the
gins. Paliform lobes not greatly developed.
olumella tangle large, about 1.5 mm. in diameter, more than one-
l the diameter of the calice; its upper surface forms the flattish
ently concave bottom of the calices.
calities and geologic horizon.—Canal Zone, stations 6015 and 6016,
ries in the Emperador limestone, Empire, T. W. Vaughan and
. MacDonald, collectors.
ype.—Figured specimen No. 325058, U.S.N.M.
ratypes.—No. 325057, U.S.N.M.

GONIOPORA PANAMENSIS, new species.

Plate 142, figs. 2, 2*a*, 2*b*.

Corallum forms thick plates, which may be more than 17 cm. wide
as much as 5 cm. thick in the center, thin on the edges. Growth
form similar to that of *Goniopora hilli*.
Calices large, but irregular in size and distribution, because of the
irregular development of intercorallite reticulum, which in some areas
rises upward and forms nipple-shaped peaks in the angles between
entirely circumscribed calices or forms ridges with calices on each
side. The diameter of the calices ranges from 2.5 to 3.5 mm.; the
bounding walls or ridges range up to 2.5 mm. thick, their length
rises up to 13 mm., where as many as three calices occur in a single
ridge, their height ranges up to 2 mm. Costae can be traced across
the intercorallite walls and the ridges between calicinal series.
Septa rather thick, about 24, arrangement indefinite, but according
to gonioporid plan; they slope to the bottom of the calice or their
inner part is narrow and falls steeply to the level or the columella
tangle, to which the primaries and secondaries extend. Three or
four indentations on the margin of each large septum. Paliform knots
present, but lobes are not conspicuous.
Columella tangle well developed, but not so large as in *G. hilli*.
Localities and geologic horizon.—Canal Zone, stations 6015 and 6016,
Emperador limestone, Empire, collected by T. W.
Vaughan and D. F. MacDonald.
Anacilla, station 6894, Crocus Bay, collected by T. W. Vaughan.
Type.—Figured specimen, No. 325053, U.S.N.M.
Paratypes.—No. 325054, U.S.N.M.

GONIOPORA DECATURENSIS, new species.

Plate 143, figs. 1, 1*a*.

Corallum lamelliform, the lateral expansion far exceedin thickness. The specimen selected as the type is a portion of a cr lum, 90 mm. across and about 23 mm. thick. Another specim 49 mm. long, 35 mm. wide, and 7.5 mm. thick. The upper su is plane or undulate. When the corallum is foliaceous, it ma irregularly flexed.

Calices polygonal, shallow, superficial or only slightly excavte Usual diameter 2.5 to 3 mm. The wall, when somewhat worn, usal has a membraniform appearance, being almost continuous, te rupted in places, but forming a quite distinct boundary betwee a jacent calices. In other instances there may be no well-d n boundary to the calices. Two rows of synapticulae frequently ei force the wall in the peripheral portion of the interseptal cu

Septa of variable thickness on the same specimen, usually no erately stout; on the thinner lamellae they are thick. The thi ne of the septa seems to be correlated with the thickness of the c on When the corallum is thick the septa are thin and *vice versa*. Th normal number is 24, although there are in some places a few 1 s, others a few more. The usual arrangement is six primaries ext di directly to the axis, with a triplet group of a secondary and tv te tiaries between each pair. A directive plane could be obser d some calices, but the septa are too much damaged to permit ce ering all the details of the arrangement. The margins are de ta five to seven dentations on each longer septum. The faces wi th usual granulations. Synapticulae rather abundant, but not gr at crowded, variable in thickness.

Columella tangle well developed.

The texture of the corallum is of variable firmness, dependin up the thickness of the septal trabeculae, the synapticulae, etc ho ever, it seems never to be especially dense.

Localities and geologic occurrence.—Georgia, station 3381 Bl Springs, 4 miles below Bainbridge; and station 3383, Hale's La din 7 miles below Bainbridge, Flint River, Decatur County, in the up the Chattahoochee formation, collected by T. W. Vaughan.

Cuba, station 7523, Mogote Peak, 250 feet a. t., ½ mile east of U. Naval Reservation, Guantanamo, Cuba, collected by O. E. Min

Type.—No. 325031, U.S.N.M.

Besides the lot of specimens referred to the species in th fo going description, three other types or kinds of *Goniopora* occur Flint River at Blue Springs and Hale's Landing. It is impossi with the material at hand to decide whether they are distinct spec or only varieties or forms of *G. decaturensis*. However, as it seem

y probable that two of these are only varieties of *G. decaturensis*, y are named and described as such.

GONIOPORA DECATURENSIS var. SILICENSIS, new variety.

Plate 143, figs. 2, 2*a*.

his is a specimen 113 mm. long, 54 mm. wide, and 20 mm. thick. upper surface is slightly undulated, there is one deep depression, it may have been caused by a burrowing animal or the surface have been corroded.

alices 2.5 to 4 mm. in diameter, larger than in typical *G. decaturen-* Septa decidedly thin; texture light and fragile.

ocality and geologic occurrence.—Georgia, station 3381, Flint River, Springs, 4 miles below Bainbridge, in the base of the Chatta-hee formation, collected by T. W. Vaughan.

ype.—No. 325026, U.S.N.M.

GONIOPORA DECATURENSIS var. BAINBRIDGENSIS, new variety.

Plate 143, figs. 3, 3*a*.

vo small, inflated, rounded specimens are referred to this variety. 1, length 26.5 mm., width 25 mm., thickness 13.5 mm.; 2 (type), length 33 mm., width 24 mm., thickness 19 mm.

lices superficial, about 3 mm. in diameter.

ota moderately thick.

ese specimens are separated from typical *G. decaturensis* solely e growth form.

ality and geologic occurrence.—Georgia, station 3381, Flint River, Springs, 4 miles below Bainbridge, in the base of the Chatta-hee formation, collected by T. W. Vaughan.

ype.—No. 325029, U.S.N.M.

GONIOPORA REGULARIS (Duncan).

1863. *Alveopora daedalaea* var. *regularis* DUNCAN, Geol. Soc. London Quart. Journ., vol. 19, p. 426, pl. 14, figs. 4*a*, 4*c*.

1867. *Alveopora daedalaea* DUNCAN, Geol. Soc. London Quart. Journ., vol. 24, p. 25.

1901. *Alveopora regularis* VAUGHAN, Geolog. Reichs. Mus. Leiden Samml., ser. 2, vol. 2, p. 71.

Duncan's material of this coral is very poor, consisting of casts and al replacements of the original skeleton; and, as I pointed out paper cited in the synonomy, he incorrectly gave the dimensions the corallites. The diameter is not "½ line" [=about 1 mm.] as by Duncan, but is usually 2 mm., with a range from 1.5 to 2.5 m. I have three photographs of Duncan's type (No. 12949, Coll. Soc. London), and after having made a large collection in a identify with certainty the species represented by Duncan's specimen. It is a species of *Goniopora* and is one of the common-corals in Antigue, where I obtained about 30 good specimens.

The corallum is usually more or less turbinate in shape, rising by a narrow base, expanding upward, with a lobulate, but somewhat flattish upper surface. The dimensions of the largest specimen are as follows: Least diameter of fracture on basal surface, 5 cm.; height 8 cm.; diameter of upper surface 22 by 25.5 cm. Some specimens are more or less columniform; others are glomerate.

The calices are from 2 to 2.5 mm. in diameter and are separated by distinct, straight walls, or there is some costate intercorallum reticulum.

The septal formula is normal for *Goniopora*, but the septa are more distinctly lamellate than is usual. There is a wide, detached, septal granule, that is usually compressed in the septal plane and is plate-like. Pali well developed; plate-like in many calices.

This species will be described in detail and figured in a forthcoming report.

Localities and geologic occurrence.—Antigua, at nearly every exposure of the coral reef in the Antigua formation, collected by T. W. Vaughan.

Porto Rico, zone C, near Lares, collected by Bela Hubbard, the New York Academy Porto Rico investigations.

Arube, Serro Colorado.

GONIOPORA REGULARIS var. MICROSCOPICA (Duncan).

1863. *Alveopora microscopica* DUNCAN, Geol. Soc. London Quart. Journ., 1. p. 426, pl. 14, fig. 5.

1867. *Alveopora microscopica* DUNCAN, Geol. Soc. London Quart. Journ., 1. p. 25.

Duncan based *Alveopora microscopica* on a silicified specimen (No. 12951, Coll. Geol. Soc. London), of which I have a photograph. This is a small calicled species of *Goniopora*, with rather strongly lamellate septa. I obtained in Antigua three specimens that I identify with Duncan's species, which probably is only a variety of *Goniopora regularis*. *G. microscopica* has a more regularly rounded corallum and smaller calices, 1.25 to 1.5 mm. in diameter; otherwise I detect no important differences.

Locality and geologic occurrence.—Antigua, stations 6856, Jarvis Hill, and 6881, Willoughby Bay, Antigua formation, collected by T. W. Vaughan.

GONIOPORA JACOBIANA, new species.

Plate 144, figs. 1, 1*a*, 2, 2*a*, 3, 3*a*.

A description of the type (pl. 144, figs. 1, 1*a*), is as follows: corallum obtuse, columniform. Horizontal diameter 160 by 165 mm. height 133 mm. +, top damaged, when perfect probably about 2[illegible] mm. tall. Successive shells of skeletal substance are recognizable.

Calices shallow, polygonal in outline, usual diameter slightly more than 3.5 mm. Intercorallite walls rather narrow, with some tissue lum, septa traceable through it, in places about 1 mm. wide.

Septa thin, formula complete, arrangement typical. Margins with average of 5 or 6 delicate teeth between the columella and the ll, 8 teeth were counted on each of a few septa. There is no conspicuous palar crown.

Columella tangle weakly developed; apparently a central tubercle s present in a number of the calices.

Locality and geologic occurrence.—Cuba, station 3446, La Cruz rl, first deep cutting east of La Cruz near Santiago, collected by W. Vaughan (type).

Florida, station 6775, White Springs, Alum Bluff formation, col- ed by T. W. Vaughan and C. W. Cooke.

Type.—No. 325077, U.S.N.M.

There are two undescribed species of *Goniopora* that are nearly ted to *G. jacobiana.* One of them is from the Chipola marl mem- of Alum Bluff formation, Chipola River, Florida. Its calices are he same size and its septa are fragile as in *G. jacobiana,* but the rcorallite reticulum is a more curly mesh-work in which the al skeletal elements are obscure or are less conspicuous than in *acobiana.* This difference in the reticulum seems to constitute a d-specific distinction. The other closely related species is from Bowden marl, Bowden, Jamaica. As the calices of the Bowden imen average about 2.3 mm. in diameter, they are distinctly ller than in *G. jacobiana.* The radial elements are obvious in intercorallite reticulum, but it is somewhat flaky. The Bowden imen may belong to *G. jacobiana,* but with the small amount of erial for comparison, it must, for the present be considered inct.

addition to the two species mentioned, there is a somewhat ar species found abundantly in the calcareous marl of Anguilla, he I collected about 50 specimens of it. This species forms laniform or gibbous masses, composed of successive caps. It is o massive as *G. jacobiana,* the columns are more slender, and lices are more excavated.

he only observed difference between the type of *G. jacobiana* he specimen from White Springs, Florida, identified with that es, is that the calices of the White Springs specimen may be what deeper. To refer specimens so simllar in habit and struc- detail to different species appears unjustifiable.

GONIOPORA IMPERATORIS, new species.

Plate 142, figs. 3, 3*a*.

Growth form as a compressed, lobate column, 54 mm. tall, 22 mm. ic 37 mm. wide (excluding a lateral lobe which is about 13 mm. ng

Calices sunken between a rather regular mural network, diameter of calicular openings 1.5 to 2.5 mm., diameter measured between mural summits 2.5 to 3.5 mm., depth about 0.75 mm., separating walls from 0.75 to 1.25 mm. wide. The walls are rather flat-topped and are composed of costal prolongations of the septa joined together by synapticulae. In places there is considerable intercorallite reticulum, but it does not form protuberances between the calices; where the surface is well preserved, subequal costae extend across the walls.

Septa of normal gonioporid arrangement, in the typical form lamellar above the bottom of the calices they are narrow, extending down the insides of the walls as short ribs, which bear about three inwardly projecting dentations; at the bottom of the calice they widen and the primaries and secondaries extend to the columellar tangle. Feebly developed paliform lobes occur just inside the junction of the tertiaries with the secondaries and form a crown around the periphery of the columellar tangle. Width of interseptal loculi less than the thickness of the septa.

Columellar tangle well developed, large, forms a flattish boss to the calices, width about one-half the calicular diameter.

Locality and geologic occurrence.—Canal Zone, station 6016, quarry in the Emperador limestone, Empire, collected by T. W. Vaughan and D. F. MacDonald.

Anguilla, stations 6893, 6894, 6966, 6967, all coralliferous beds at Crocus Bay; station 6969*a*, bottom bed, Road Bay, collected by T. W. Vaughan.

Type.—No. 325049, U.S.N.M.

This species really should have been based on the Anguillan material, of which I collected 34 identifiable specimens. In fully developed colonies the branches are subcircular or elliptical in cross section, and range from 30 to 55 mm. in diameter. The distance between mural summits ranges up to 4.5 mm. but is usually less

GONIOPORA CANALIS, new species.

Plate 146, figs. 1, 2, 3.

Corallum composed of compressed branches. The following are measurements:

Dimensions of branches of Goniopora canalis.

Branch No.	Length.	Greater diameter of lower end.	Lesser diameter of lower end.	Maximum thickness.
	mm.	*mm.*	*mm.*	*mm.*
1	41	20	6.5	30
2	41	20	12	28
3		22	8	35
4			7.5	20

The lower end of each specimen and the tops of Nos. 3 and 4 are broken. Some coralla are evidently formed of rather thin, branching plates.

Calices polygonal, usual diameter 3 mm., young calices about 2 mm. in diameter, an occasional large one as much as 4 mm.; depth from 1 to 1.25 mm.: separated by walls from 0.75 to 1.25 mm. thick. The walls are crossed by costae and usually form a fairly regular network around the calicular cavities, but in places there is considerable intercalicular reticulum. In places there are low, rather indefinite ridges which may extend the length of as many as four calices. The tops of the walls are rounded or subacute.

The septa are normal gonioporid in number and arrangement; they are thick at the wall, becomes thinner toward the center; their upper part narrow, gradually sloping to the columella tangle, which is joined by the primaries and secondaries; margins with about nine dentations.

Columella tangle not very conspicuous.

Locality and geologic horizon.—Canal Zone, station 6016, quarry in the Emperador limestone, Empire, collected by T. W. Vaughan and J. F. MacDonald.

Anguilla, station 6966, middle bed, Crocus Bay, collected by T. W. Vaughan.

Cotypes.—Nos. 325052, U.S.N.M. (3 specimens).

I am not certain the *G. canalis* is really different from *G. imperatis*.

GONIOPORA PORTORICENSIS, new species.

Plate 146, figs. 4, 5.

Corallum ramous, branches rounded in cross section or very compressed, a branch of the latter form is 34 mm. wide with a maximum thickness of about 9 mm.

Calices polygonal, shallow, usual diameter 2 mm. The outer ends of the septa are flattened and fused together, separating the calicular depressions by a wall about 0.5 mm. thick.

Septa delicate, very perforate, in three complete cycles. Margins finely and delicately denticulate; about five small thin teeth on a big septum. Pali appear to be poorly developed, not specially differentiated from the ordinary septal dentations.

Columella weakly developed.

Locality and geologic occurrence.—Porto Rico, station 3191, 4 miles west of Lares, Pepino formation, collected by R. T. Hill.

Antigua, stations 6854, Rifle Butts; 6881, Willoughby Bay, in the Antigua formation, collected by T. W. Vaughan.

Type.—No. 325061, U.S.N.M.

Paratype.—No. 325060, U.S.N.M.

This species resembles compressed specimens of *Goniopora clevei* Vaughan, from which it is distinguishable by its thin septa, with delicately dentate margins.

GONIOPORA CLEVEI, new species.

Plate 145, figs. 1, 2, 2*a*, 3, 4, 5, 5*a*, 6, 6*a*.

Corallum branching. The type (pl. 145, figs. 2, 2*a*) is an irregularly shaped portion of a branch, selected because it permits the septal arrangement to be definitely determined. It is 44 mm. long; greater diameter of lower end, 12 mm.; of bulged portion, 15.5 mm. Probably some of the irregularity of form may be caused by erosion. Another broken specimen, a paratype, is represented by plate 5, figure 1.

Calices shallow, circular, or subcircular, 2 to 2.4 mm. in diameter. They may be close together or separated by reticulate and costate coenenchyma, as much as 1 mm. across; usually in the type, which is worn, they appear distinctly separated from the bounding coenenchyma and sharply defined by a peripheral zone of synapticulae.

There are 12 large lamellate septa with typical poritid arrangement, solitary directive, four lateral pairs, and a directive triplet; the inner ends of the laterals in the triplet are directed toward, but not actually fused, to the inner end of the principal directive. The outer end of these larger are often bifurcated, or costae (these are to be considered rudimentary septa) exist between them, in some instances bringing the number up to 24. Pali well developed, six in number.

Columella tangle rather dense, with an axial tubercle.

Locality and geologic occurrence.—Island of Anguilla, West Indies, P. T. Cleve, collector (type); stations 6893, 6894, 6966, Crocus Bay, and 6970, 130 to 140 feet above sea level, east end of Road Bay, Anguilla, collected by T. W. Vaughan.

Canal Zone, station 6016, in the Emperador limestone, collected by T. W. Vaughan and D. F. MacDonald.

Antigua, station 6854, Rifle Butts, Antigua formation, collected by T. W. Vaughan.

Type.—University of Upsala.

Paratype.—University of Upsala.

Paratypes.—Nos. 325111 (3 specimens), 325115 (1 specimen), U.S.N.M.

It was decidedly difficult to decide whether this species should be referred to *Porites* or *Goniopora*. Bernard says: "These fossils with 12 central rays might almost be considered as transition forms toward *Porites* having to all appearance only 12 septa; but whenever it can be distinctly seen that a certain number of these septa fork before they reach the wall, I assume that the forking is the vestige of the fusion of the septa characteristic of *Goniopora*, and that therefore there are more than 12." [1]

[1] Brit. Mus., Cat. Madrep. Corals, vol. 4, Gen. Goniopora, p. 21.

While in Anguilla in 1914 I collected about 40 identifiable specimens of this species, and am illustrating a series on plate 145, figures , 4, 5, 5*a*. The branches are thickish and blunt-ended, having some esemblance in growth form to the thicker-branched forms of *Porites orites*, such as are common on the reefs on the east side of Andros sland, Bahamas. The calices of these specimens are not perfectly reserved, but in many a third cycle of septa is clearly recognizable. therefore am convinced that the species is referable to *Goniopora*. Doctor MacDonald and I collected in the quarries at Empire, Canal one, a number of specimens that seem completely to agree with the nguillan specimens. One of these is represented by plate 145, gures 6, 6*a*.

Flattened specimens of *G. clevei* resemble specimen of *G. portorinsis*, but the latter has thinner and more delicately dentate septa, id in it the tertiary septa are more developed.

GONIOPORA CASCADENSIS, new species.

Plate 146, figs. 6, 6*a*, 6*b*, 7, 8, 9.

Corallum composed of relatively slender, subterete branches. A anch segment 40 mm. long is 9 by 10 mm. in diameter at the lower d and 8 by 9 mm. in diameter at the upper end, showing 1 mm. crease in diameter for 40 mm. in length; but branches may be icker, up to as much as 15 mm. in diameter.

Calices slightly excavated, polygonal, from 1.75 to 2.5 mm. in ameter, separated by more or less discontinuous walls, in some aces a straight or zigzag wall ridge is traceable, but in other places ere seems to be none. Where there is a wall ridge, rather coarse ural denticles corresponding to the outer ends of the septa are esent. In places mural reticulum is present and coarse radial skelet structures are clearly traceable through it.

There are 12 large septa which extend to the columellar tangle, d about 12 small septa which fuse in pairs to the sides of an included ptum (assumed to a secondary) about halfway between the wall d the columellar tangle. The septal granules seem to be arranged ording to the following scheme: A ring of outer granules which a adherent to or only slightly detached from the wall, a ring of ermediate granules which correspond in position to the place of ion of the small (tertiary) septa to the sides of the secondaries, d an inner ring of granules which form paliform knots around the piphery of the columella tangle. The intermediate and inner rings m constantly recognizable, but the outer ring is not always definely developed. The interseptal loculi are about as wide as the kness of the septa.

Columella tangle well developed; width more than one-third the meter of the calice. In some calice a central styliform process is inguishable.

Locality and geologic occurrence.—Canal Zone, station 6020*c*, in the Culebra formation at Las Cascadas, collected by T. W. Vaughan and D. F. MacDonald.

Anguilla, station 6967, Crocus Bay, collected by T. W. Vaughan.

Antigua, station 6854, Rifle Butts, Antigua formation, collected by T. W. Vaughan.

Type.—No. 325072, U.S.N.M. (pl. 146, figs. 6, 6*a*, 6*b*).

Paratypes.—No. 335074, U.S.N.M. (3 specimens).

This species is one of those that is intermediate between *Porites* and *Goniopora*. As there are short tertiary septa within the wall, according to Bernard's treatment of such forms, it is referred to *Goniopora*.

The types are from Las Cascadas, Canal Zone. The calices of the specimens from Anguilla are not so well preserved as those of the cotypes, but the identifications seem reasonably certain, as there is agreement in all general characters and in the observed detail.

Genus PORITES Link.

1807. *Porites* LINK, Beschreibungen der Naturaliens Sammlungen, Rostock, p. 162.

1918. *Porites* VAUGHAN, Carnegie Inst. Washington Pub. 213, p. 138.

Type-species.—*Madrepora porites* Pallas.

PORITES PORITES (Pallas).

1766. *Madrepora porites* PALLAS (part), Elench. Zooph., p. 324.

1901. *Porites porites* forma *clavaria* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 316, pl. 29; pl. 31, fig. 2.

1902. *Porites porites* VAUGHAN, Biol. Soc. Washington Proc., vol. 15, pp. 56–58 (with references to literature and history of the name).

1909. *Porites porites* var., VAUGHAN, Carnegie Inst. Washington Yearbook No. 7, p. 135.

1912. *Porites clavaria* VAUGHAN, Carnegie Inst. Washington Yearbook No. 10, p. 148, 152, 156, pl. 4, fig. 4*c*; pl. 6, figs. 3, 4.

1915. *Porites clavaria* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 597.

1916. *Porites clavaria* VAUGHAN, Nat. Acad. Sci. Proc., vol. 2, pp. 95, 98.

1916. *Porites clavaria* VAUGHAN, Carnegie Inst. Washington Yearbook No. 1[illegible] p. 228.

This is one of the species of corals to which most attention was given during my studies of the Floridian and Bahamian reef corals, and it is referred to in most of my reports in Yearbooks No. 7–14, inclusive, of the Carnegie Institution of Washington, usually as *Porites clavaria*, because that is the more generally known name.

Localities and geologic occurrence.—Recent throughout the coral-reef areas of the West Indies, the eastern side of Central America, Florida, and the Bermudas.

Pleistocene, in the elevated West Indian reefs.

Miocene, Santiago, Cuba, in the La Cruz marl, at station 3441, east f La Cruz, near crossing of the road from Santiago to the Morro ver the railroad, collected by T. W. Vaughan. As these specimens gree in all details that I can discover, with the thicker-branched rms of *P. porites*, I am referring them to that species. This adds nother to the considerable list of living species recognized in the a Cruz marl.

PORITES FURCATA Lamarck.

1816. *Porites furcata* LAMARCK, Hist. nat. Anim. sans Vert., vol. 2, p. 271.
1887. *Porites furcata* RATHBUN, U. S. Nat. Mus. Proc., vol. 10, p. 361, pl. 15, figs. 1–3; pl. 17, fig. 1.
1901. *Porites porites* forma *furcata* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 316, pl. 30; pl. 31, fig. 1.
1902. *Porites polymorpha* VERRILL (part), Conn. Acad. Arts and Sci. Trans., vol. 11, p. 158.
1913. *Porites furcata* VAUGHAN, Carnegie Inst. Washington Yearbook No. 10, p. 156, pl. 5, figs. 5*c*, 6*c*, 7, 8; pl. 6, figs. 1*a*, 1*b*, 2*a*, 2*b*.
1915. *Porites furcata* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 597.
1916. *Porites furcata* VAUGHAN, Nat. Acad. Sci. Proc., vol. 2, p. 95.
1916. *Porites furcata* VAUGHAN, Carnegie Inst. Washington Yearbook No. 14, p. 228.

Localities and geologic occurrence.—Canal Zone, Pleistocene at sta- ons 5850 and 6039, Mount Hope, and 6554, dug out of mud flat, out 1 foot above ordinary high-tide level, Colon, collected by D. F. acDonald.

Costa Rica, Moin Hill, Niveau *a*, H. Pittier collection.

Porites furcata is a common Pleistocene species. It is usual in the aterial behind elevated, sea-front reefs of the West Indies and east- n Central America, and it is one of the most abundant corals on te flats inside the living coral reefs in the same region and Florida. has not been found in Bermudas.[1]

PORITES BARACOÄENSIS, new species.

Plate 147, figs. 1, 1*a*.

Corallum composed of slender branches. The type, a fragment of branch, is 26 mm. long; lower end, subcircular in cross section, 6.25 m. in diameter; 8.5 below upper end, the diameter is 6 by 8 mm., owing some flattening just below a bifurcation.

Calices polygonal, excavated but rather shallow; diameter from 1.5 to 2.25 mm., about 1.75 mm. usual. Wall straight, acute or with ther coarse knots corresponding to the outer ends of the septa; a distinct mural shelf is present in all or nearly all calices.

Septa arranged into a solitary directive, four lateral pairs, and a central triplet. There is a circle of septal granules detached from the wall and fused by their bases, forming a mural shelf on the inner margin of which the granules stand up as compressed knots or as

[1] See Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 158, 1902.

plates. Usually there are six pali; that is, normally there are p
before the lateral pairs, the solitary directive, and the triplet. In
few calices there is a palus before each member of the triplet, maki
eight pali in all; and in a few calices there is no recognizable pal
before the solitary directive, the total number of pali being only fi
The pali are solidly fused in the bottom of the calice one to anoth
and to the columella tangle. No columellar tubercle was seen
any calice.

Locality and geologic occurrence.—Miocene, Cuba, station 3476, m
Baracoa, collected by T. W. Vaughan (type).

Miocene, Jamaica, Bowden marl, Bowden, received from H
T. H. Aldrich.

Type.—No. 325069, U.S.N.M.

There is no other previously described species of *Porites*, fossil
living, in tropical or subtropical America closely resembling
baracoäensis. Superficially it looks like the living *P. furcata* Lam
or *P. divaricata* Le Sueur; but the definite mural shelf, above wh
the wall stands at its distal edge and the special granules on its in
edge, is distinctive.

PORITES BARACOÄENSIS var. MATANZASENSIS, new variety.

Plate 147, figs. 2, 2*a*, 3, 4.

Corallum composed of attenuate branches of small diameter.
fragment 15 mm. long is 3 mm. in diameter at one end and 3.25 m
in diameter at the other. The maximum diameter of a branch see
to be about 3.75 mm., except where there is some flattening j t
below a bifurcation. The length of branches exceeds 20 mm., d
probably is as much as 40 to 50 mm., or even more.

Calices polygonal, very shallow or even surficial; diameter fr
2 to 2.75 mm. Wall slightly elevated, continuous and acute or w
knots corresponding to the outer ends of the septa. Usually ther
a distinct mural shelf.

The septal characters are the same as those of *P. baracoäensis*,
cept that the pali are less conspicuous and the septa in the upper l
of the calice are usually elongated and have between three and
teeth on their margins between the wall and the columella tan
But in some calices the upper septa are not produced, and in th
the septal characters are the same as in typical *P. baracoäensis*.
cause of the presence of calices presenting the same characters
those of typical *P. baracoäensis*, a varietal designation seems all t
is justifiable.

Locality and geologic occurrence.—Miocene, Cuba, station 34
marl, gorge of Yumurí River, Matanzas, collected by T. W. Vaugh

Type.—No. 325067*a*, U.S.N.M. (pl. 147, figs. 2, 2*a*.).

Paratypes.—Nos. 325067*b*, U.S.N.M.

Apparently the specimens from Yumurí gorge lived in deeper or ieter water than those from Baracoa, for the differences are of the ld incident to such differences in ecologic conditions. The speci- ens of *Stylophora granulata* from the Yumurí gorge are decidedly ore attenuate than those from Baracoa; and the specimens referred *Madracis mirabilis* are very slender and fragile.

PORITES DOUVILLEI, new species.

Plate 149, figs. 2, 2*a*; plate 151, figs. 1, 1*a*.

Corallum composed of compressed, more or less coalescent branches. late 151, figure 1, represents a part of a corallum 66 mm. long, 1 mm. in maximum thickness, and 40 mm. wide; the specimen, resented by figure 2 of plate 149, is 35.5 mm. long and 11 mm. maximum thickness.

Calices shallow, polygonal, 1.25 to 2 mm. in diameter, 1.5 mm. bably about an average; separated by usually continuous, straight, mbraniform walls, along the top of which are a few mural denticles responding to the outer ends of the septa; where the septa are ally forked there may be a denticle for each fork.

epta forming four lateral pairs, two on each side of the plane of mmetry, a solitary directive, and a ventral triplet with the inner s of its members free from each other. A ring of thickish septal nules is detached from the wall, standing about half way between nd the palar ring; the outer ends of a number of septa fork ween the septal granule and the wall. Pali well-developed, onula complete or suppressed on one or more members of the rlets, suggestions of trident formation in some calices. Synapti- ue in two rings, the outer corresponds in position with the septal nules and is usually incomplete, the inner is the palar synapticular and normally is complete.

olumella tangle consists of a central tubercle joined by radii to h pali.

ocality and geologic occurrence.—Canal Zone, station 6016, quarry he Emperador limestone, Empire, collected by T. W. Vaughan d D. F. MacDonald.

types.—Cat. No. 325106 (2 specimens), U.S.N.M.

PORITES TOULAI, new species.

Plate 150, figs. 1, 1*a*, 2, 3, 4.

rallum composed of elongate, rather slender, subterete, or only ligtly compressed branches. The following measurements of ree branches indicate the shape and size.

Measurements of branches of Porites toulai.

Specimen No.	Length.	Diameter of lower end.	Diameter of upper end
	mm.	*mm.*	*mm*
1	40.5	7 by 8	6.75 by 5
2	46	13.5 by 14	12 by
3	74	11 by 17	8 by 5

Specimen No. 3 has been somewhat compressed by pressure.

Calices shallow, diameter about 1.75 mm., a few large calices h e a greater diameter of as much as 2.5 mm. There is a pronoun d tendency for the calices to occur in rather short, longitudinal se s. One series is 5.5 mm. long and contains 4 calices, one of whic l is immature; another series, which is slightly curved, is 7.5 mm. l g and contains 5 calices. The calices within a series are separated y indistinct walls; in fact, between some no definite wall is recog z- able, the distal ends of septa from one calicinal center being cont i- ous with the distal ends of the septa belonging to the next cen r. Such series are formed by fission. The walls between adjacent se es are definite; a wall-ridge is usually but not invariably recogniza e, it is interrupted and straight or somewhat zigzag. There is in pl es a considerable development of intercalicular or interserial reticul n, in which the radial (costal) skeletal elements are conspicuous.

The septal arrangement is irregular as would be expected in a c al in which asexual reproduction is largely by fission. Groups of ca es from two specimens are shown on plate 150, figures 1*a*, 4. he scheme where complete seems to be a solitary directive, two la al pairs on each side of the plane of symmetry, and a ventral tripl in which the inner ends of the lateral members converge toward he included directive and join it by synapticulae, but such a schem ic arrangement is rarely recognizable. There are usually from 10 t 14 septa fusing in pairs or in threes, with a solitary septum, the dire ve plane being indicated in many calices by an elongate septum, t he inner end of which the columellar tubercle may be attached. Usu lly coarse septal granules slightly detached from the wall form a g, and the pali form a ring surrounding the columellar tangle. T re is indefiniteness and irregularity in the pali as there is in the se a; the normal number seems to be five or six. There are an outer ng of synapticulae, more or less fused to or detached from the wall nd an inner palar ring.

There is a well developed, rather prominent columellar tub le, which is joined by radii to the inner ends of the septa.

Locality and geologic occurrence.—Canal Zone, station 6016, q ry in the Emperador limestone, Empire, collected by T. W. Vau an and D. F. MacDonald.

Type.—Cat. No. 325105*a*, U.S.N.M. pl. 150, figs. 1, 1*a*.

Paratypes.—Cat. No. 325105*b*, U.S.N.M. (3 specimens).

PORITES ASTREOIDES Lamarck.

1816. *Porites astreoides* LAMARCK, Hist. nat. Anim. sans Vert., vol. 2, p. 269.
1887. *Porites astreoides* RATHBUN, U. S. Nat. Mus. Proc., vol. 10, p. 354.
1901. *Porites astreoides* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol. 2, p. 317, pl. 32; pl. 33; pl. 34, figs. 1, 2.
1902. *Porites astreoides* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 160, pl. 31, fig. 4.
1902. *Porites verrilli* VERRILL, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 161, pl. 31, fig. 5.
1903. *Porites astraeoides* DUERDEN, Nat. Acad. Sci. Mem., vol. 8, p. 550, pls. 3–5, figs. 28–42.
1912. *Porites astreoides* VAUGHAN, Carnegie Inst. Washington Yearbook No. 10, pp. 148–156, pl. 4, figs. 3*a*, 3*d*, 3*e*; pl. 5, figs. 5*b*, pl. 6, figs. 1*c*, 2*e*.
1915. *Porites astreoides* VAUGHAN, Washington Acad. Sci. Journ., vol. 5, p. 597.
1916. *Porites astreoides* VAUGHAN, Nat. Acad. Sci. Proc., vol. 2, p. 98.
1916. *Porites astreoides* VAUGHAN, Carnegie Inst. Washington Yearbook No. 12, pp. 226, 227, 228, 231.

This is one of the coral species to which I devoted much attention during my field studies in Florida and the Bahamas. The results of my observations and experiments have mostly been published in Yearbook Nos. 7 to 14, inclusive, of the Carnegie Institution of Washington.

Localities and geologic occurrence.—Canal Zone, Pleistocene, station 30, Mount Hope, collected by D. F. MacDonald. This species is general in both the living and the Pleistocene coral reefs of the Caribbean region and Florida. It is also found living both in the Bermudas and on the Brazilian reefs.[1]

Also collected in the Miocene La Cruz marl in and near Santiago, Cuba, a number of specimens of a massive species of *Porites* that I can not distinguish from *P. astreoides*. The station numbers are 3434 and 3438, south side of the city along the trocha; 3446, first deep cutting east of La Cruz, along the railroad.

PORITES PANAMENSIS, new species.

Plate 148, figs. 1, 2, 3, 3*a*.

The type is the upper part of a plate, which is 90 mm. tall, 75 mm. wide, and 28 mm. in maximum thickness near the lower end. One side is nearly flat, while on the other there are two low gibbosities. (See pl. 148, fig. 3.)

Calices excavated but not very deep, circumscribed, 1.5 to 2 mm. in diameter, or confluent in short series of about three calices. Wall coarse, rather ragged in appearance, forms a considerably interrupted, usually straight, occasionally zigzag, elevated ridge with coarse knots on its top. As asexual reproduction is largely by fission, there are no definite walls between many calicinal centers.

[1] Verrill, Conn. Acad. Arts and Sci. Trans., vol. 11, p. 161, 1902.

There is irregularity in the number and arrangement of the se resulting from the formation of new calices by fission. They usually rather thick and in many calices are bent in an irregular w In fully developed calices there are 12 septa with the usual soli directive, four lateral pairs, and a directive triplet. The lateral the triplet are more or less free from the directive of the group, usually appear to converge toward its inner end. Septal gran irregular in development, rarely forming a definite, clear-cut r more or less attached to the wall. Pali from six to eight in num irregular in development. No definite outer synapticular ring, a few synapticulae correspond in position to the septal granules; p synapticular ring better developed.

There is a columellar tubercle rising in the middle of an irreg columellar tangle.

Locality and geologic occurrence.—Canal Zone, stations 6015 6016, quarries in the Emperador limestone, Empire, collected T. W. Vaughan and D. F. Macdonald.

Type.—No. 325063, U.S.N.M.

Paratypes.—Nos. 325064, U.S.N.M. (2 specimens).

The type and three other specimens are plates with undulatio low gibbosities on the sides. This growth-form grades into nc columns (see pl. 148, fig. 1, for growth habit, and fig. 2 for an enla view of the calices of another specimen of similar growth-form). A the good suite of specimens shows that these are only intergr growth-forms of the same species and as they occur together at tion 6016, separate nomenclatorial designation appears unnece

PORITES ANGUILLENSIS, new species.

Plate 149, figs. 1, 1*a*, 1*b* (type); plate 150, fig. 5.

The following is a description of the type: Corallum compos thin, more or less undulate, separate laminae, resting one on an The underside epithecate to the edge, the epitheca minutely, regu and concentrically striate. The type-specimen consists of two u laminae, both broken. The greatest thickness of the two is 15 mm., the greatest width 58 mm. One lamina is 5 mm. thick thickest portion, the edge is thinner.

The calices are shallow, subcircular, 1.7 to 2.3 mm. in dia separated by flat coenenchymal walls, 0.8 to 1 mm. across. T coenenchyma is perforate, but rather compact and costate.

Septa rather thick, normal number 12, with solitary dir four lateral pairs, and the laterals on the sides of the principal tive loosely fused to it or continued to the columella tangle. usually six in number, before the lateral pairs, on the ends solitary and principal directives. As a rule, there is a pro dentation at the inner edge of the wall. Synapticulae well dev

ree rows in the wall, and a ring of thick ones, coinciding with the alar ring, around the axis of each corallite. Trabeculae of columellar ngle coarse; axial tubercle present. In longitudinal section there e in 3.5 mm. about 11 synapticulae; in the same distance about 10 rtical rods. The spaces of approximately the same thickness as e solid parts, except that the median portion of a synapticula is inner than its ends.

Locality and geologic occurrence.—Island of Anguilla, West Indies, llected by P. T. Cleve; Crocus Bay, Anguilla, collected by T. W. ughan.

Canal Zone, station 6016, in the Emperador limestone, Empire, llected by T. W. Vaughan and D. F. MacDonald.

Type.—University of Upsala.

Duplicate specimen from the Cleve collection and other specimens the United States National Museum.

This is an abundant species at Crocus Bay, Anguilla, where I collted it in both the lower and the upper part of the exposure on the uth side of the bay. The epitheca is not always distinct on the wer surface, but I can not be sure whether it has been worn off or as not developed.

One of the two specimens from Empire, Canal Zone, is represented by plate 150, figure 5. The calicular characters are obscure but they em to be the same as those of *P. anguillensis*. The general facies of th specimens is identical with that of *P. anguillensis*.

Subgenus SYNARAEA Verrill.

1864. *Synaraea* VERRILL, Mus. Comp. Zool. Bull., vol. 1, p. 42.

Type-species.—None was designated by Verrill; therefore I select as the type-species *Porites erosa* Dana, the first species in Verrill's list of those referred by him to *Synaraea*.

PORITES (SYNARAEA) HOWEI, new species.

Plate 151, figs. 2, 2*a*, 3, 3*a*, 4.

Corallum composed of rather small, slightly or greatly compressed, even subpalmate, branches, on some of which longitudinal carinae are well developed. Plate 151, figures 2, 3, 3*a*, are natural size illustrations of two specimens. The thickness of the lower end of the specimen represented by figure 2 is 6 mm., of the upper end of the same specimen about 5.5 mm.; the width and length of the specimen are indicated by the figure.

The calices are small, about 1 mm. in diameter, and occur more or less in series from 5 to 18 mm. long between reticular coenenchymal ridges, that range in thickness from a merely dividing partition up to 2 mm. wide, and in height up to a maximum of about 1 mm.

Septa small, 12 in number, with the usual poritid arrangement. The laterals of the triplet converge toward the inner end of the direc-

tive and fuse to it at the periphery of the columellar tangle. A circle of fairly prominent septal granules distinguishable just with and more or less attached to the wall. Pali small, but distinct and relatively prominent, usually six in number, on the inner ends of the two directives and before the lateral pairs. The synapticular rings are very clearly distinguishable, apparently there are two, the outer of irregular development.

Columellar tangle well developed, with a small, erect central tubercle.

Locality and geologic occurrence.—Canal Zone, station 6016, quarry in the Emperador limestone, Empire, collected by T. W. Vaughan and D. F. MacDonald.

Cotypes.—No. 325113, U.S.N.M. (3 specimens).

PORITES (SYNARAEA) MACDONALDI, new species.

Plate 152, figs. 1, 2, 3, 3*a*, 4, 5, 5*a*.

Corallum begins growth as an explanate plate with humps and gibbosities on its upper surface, by continued growth the protuberances rise into crests and compressed columiform lobes. The series of illustrations on plate 152, figures 1, 2, 3, 4, 5, indicate the growth-forms.

Calices of moderate size, average about 1.5 mm. in diameter, occur separately or in series, usually in series which range in length from the diameter of two or three calices up to 18 mm. long with 11 calices. Within the series, although the calicinal centers are clearly demarked, the walls between adjacent calices are only slightly developed, but the series are separated by distinct fairly continuous walls, which are costate on top, or by coarsely reticular coenenchyma. In many places the reticulum rises upward between calices, especially at their corners, and forms papillae, similar to those in the papillate species of *Montipora*. Such papillae may be single, with a basal diameter of about 1 mm. and a height also of about 1 mm., or they may fuse and form ridges as much as 7 mm. long and 1.5 mm. thick at the base. The reticulum composing the papillae is of coarse texture.

As new calices are largely formed by fission, the septal arrangement is not definitely schematic. Where it appears possible to recognize a ventral directive, the laterals of the triplet are joined to it by synapticulae at the periphery of the columellar tangle. There is a ring of septal granules slightly detached from the wall, and corresponding to it in position is an incomplete ring of synapticulae; pali are present, but usually indefinite in development, in one calice there appear to be eight; palar synapticulae indefinite.

Columellar tangle composed of indefinite, confused processes om the inner ends of the septa among which an axial plate is recog- zable in a few calices.

Locality and geologic occurrence.—Canal Zone, station 6016, quar- in the Emperador limestone, Empire, collected by T. W. Vaughan nd D. F. MacDonald.

Anguilla, station 68)3, Crocus Bay, collected by T. W. Vaughan.

Cotypes.—No. 325046*a*, U.S.N.M. (4 specimens.)

The identification of the specimen represented by plate 152, ures 5, 5*a* (No. 325046*b*, U.S.N.M.), is not positive.

Class HYDROZOA.

Order HYDROCORALLINAE Moseley.[1]

Family MILLEPORIDAE L. Aggassiz.

Genus MILLEPORA Linnaeus.

MILLEPORA ALCICORNIS Linnaeus.

'58. *Millepora alcicornis* LINNAEUS, Syst. Nat., ed. 10, p. 791.
'98. *Millepora alcicornis* HICKSON, Zool. Soc. London Proc. for 1898, p. 256.
01. *Millepora alcicornis* VAUGHAN, U. S. Fish Com. Bull. for 1900, vol 2, p. 318, pls. 35–38.

ocality and geologic occurrence.—Canal Zone, Pleistocene, stations 5[illegible]0 and 6039, Mount Hope, collected by D. F. MacDonald. One of th two specimens is partly incrusted by *Polytrema mineaceum* (Linnaeus). *Millepora alcicornis* is found living on the West Indian an Floridian coral reefs nearly everywhere there are such reefs ar in the Bermudas. According to Hickson, there is only one living species, which is Indo-Pacific as well as Atlantic in its distri- bu on.

EXPLANATIONS OF PLATES.

PLATE 68.

West Indian Shore Lines.

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D. . Jean Bay, St. Bartholomew	275

PLATE 69.

West Indian Shore Lines.

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B. st side of Crocus Bay, north side of Anguilla	276
C. lls Pond, Anguilla	277
D. ore, south side of Anguilla, looking toward St. Martin	276

[1] T e organisms are not corals, but, as they are usually associated with corals and contribute calcium arb te to reefs, accounts of them are frequently included in discussion of Madreporia.

PLATE 70.

West Indian Shore Lines.

P.
A. Looking into the mouth of Charlotte Amalia Harbor, St. Thomas..... 9
B. Cliffs on southern shore of St. Thomas..... 9
C. Alluvial plain at head of an embayment, St. Thomas..... 9
D. Mountains on north, limestone plain on south, St. Croix..... 8

PLATE 71.

West Indian Shore Lines.

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B. Santiago Harbor, Cuba, looking seaward through its mouth..... 81
C. Yumuri gorge, Matanzas, Cuba..... 84
D. Yumuri Valley above the gorge..... 84

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Views of Isle of Pines, Cuba.

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B. Daguilla, a monadnock of hard rock..... 86
C. Lower part of course of Santa Fe River..... 86

PLATE 73.

Model of Gulf of Mexico and Caribbean Sea..... 99

PLATE 74.

Stylophora imperatoris, new species.

FIGS. 1, 1*a*. Two views of the type, from station 6016, Empire, Canal Zone.
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1*a*. Calices, × 8. The slightly protuberant upper calicular margins are at the right in the figure..... 334
2. A second specimen from station 6016, × 3..... 334
3. A third specimen from station 6016, natural size..... 334
4, 4*a*. Two views of a specimen from station 6894, lowest bed, Crocus Bay, Anguilla.
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Orbicella costata (Duncan).

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PLATE 100.

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Pironastraea anguillensis, new species.

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PLATE 113.

Pironastraea antiguensis, new species.

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Siderastrea dalli, new species.

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PLATE 121.

Siderastrea conferta (Duncan).

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1*a*. Calices, × 6 453
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Siderastrea siderea (Ellis Solander).

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2. Corallum, natural size
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3. Corallum, natural size
3*a*. Calices, × 6

PLATE 123.

Cyathomorpha rochettina (Michelin) Reis.

Six views of the same specimen, from Crosara, Italy.

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1*a*. Calicular view, natural size
1*b*. Basal view, natural size
1*c*. Coarse costae, × 2
1*d*. Costae at calicular edge, × 4. Shows perforations near the calicular margin
1*e*. Calice, × 4. Shows some synapticulae and that the higher cycles of septa are perforate

PLATE 124.

Cyathomorpha hilli, new species.

Two views of the type.

FIG. 1. Upper surface, natural size
1*a*. Lower surface, natural size

PLATE 125.

Cyathomorpha hilli, new species.

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1. Upper surface, natural size
1*a*. Side view, natural size
1*b*. Costae, × 2
1*c*. Calice, × 2
1*d*. Another calice, × 2
2, 2*a*. Two views of a second paratype
2. Side view, natural size
2*a*. Upper surface, natural size

PLATE 126.

Cyathomorpha browni, new species.

Three views of the type.

FIG. 1. Upper surface, natural size
1*a*. Lower surface, natural size
1*b*. Calices and costae, × 2

PLATE 127.

Cyathomorpha anguillensis, new species. All figures natural size.

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PLATE 128.

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PLATE 130.

Cyathomorpha antiguensis (Duncan) Vaughan.

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PLATE 131.

Cyathomorpha antiguensis (Duncan) Vaughan.

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1*b*. A calice, × 4, to show the prominent pali 465

FIGS. 2. A specimen, natural size, with both crowded and rather remote calices on the same corallum.

3. A specimen, natural size, most of the calices crowded, intercorallite areas very narrow, except at lower left-hand corner, where there is a distant, circular calice.

4. Duncan type of *Astroria antiguensis*, natural size, Geological Society of London. Compare with figure 2 of this plate.

PLATE 132.

FIGS. 1, 2, 2*a*, 2*b*. *Cyathomorpha antiguensis* (Duncan) Vaughan, from Porto Rico.

1. Calices, natural size.

2, 2*a*, 2*b*. Three views of the same specimen. 2, corallum, natural size; 2*a*, 2*b*, calices, × 4.

3, 3*a*. *Cyathomorpha tenuis* (Duncan) Vaughan. Two views of a specimen from Porto Rico.

3. Corallum, natural size.

3*a*. Calices, × 4.

PLATE 133.

FIG. 1. Duncan's type of *Astroria affinis*, natural size, Geological Society of London. Probably a synonym of *Cyathomorpha antiguensis* (Duncan).

Cyathomorpha tenuis (Duncan) Vaughan.

2. Calices, × 2, of a specimen, with crowded calices, from Porto Rico.

3, 3*a*, 3*b*. Three views of a specimen from Willoughby Bay, Antigua.

3. Upper surface of corallum, natural size.

3*a*. Part of upper surface, × 4, to show synapticulae between the costae.

3*b*. Costae with intervening synapticulae on lower surface, × 4.

PLATE 134.

Diploastrea heliopora (Lamarck) Matthai.

Four views of the same specimen.

FIG. 1. Upper surface, natural size.

1*a*. Costae and intervening synapticulae of lower surface, × 4.

1*b*. Calices, × 4, to show synapticulae between the distal ends of the septa.

1*c*. Longitudinal section of a corallite, × 4, to show septal perforations, synapticulae, and dissepiments.

PLATE 135.

Diploastrea crassolamellata (Duncan) Vaughan.

FIG. 1. Cross-section of the corallites of a typical specimen, natural size. Most of the septal lamellae appear dark in the figure.

2. Cross section of the corallites of a specimen representing Duncan's variety *nobilis*.

3. A young, simple corallite, side view, natural size.

4, 4*a*. Two views of the same specimen.

4. Side view, natural size.

4*a*. Calicular view, natural size.

5, 5*a*, 5*b*. Three views of the same specimen.

5. Calicular view, natural size.

5*a*. Side view, natural size.

5*b*. A calice, × 2.

PLATE 136.

Diploastrea crassolamellata (Duncan) Vaughan.

Three views of the same specimen.

Page.
1. Side view of corallum, natural size 475
1*a*. Costae of side, × 2 475
1*b*. Calices, natural size 475

PLATE 137.

Diploastrea crassolamellata (Duncan) Vaughan.

1. Specimen with excavated calices, natural size 475
2. Specimen with protuberant divergent corallites, natural size 475
3. Specimen with low corallites, × 2. Note the reticulate intercorallite area 475
4, 4*a*. Calices of the same specimen, × 2.
4. With some intercorallite reticulation 475
4*a*. Mostly without any intercorallite reticulation 475
5. Calices, natural size, of a specimen from the base of the Chattahoochee formation near Bainbridge, Georgia. All other specimens illustrated on this plate are from Antigua 475

PLATE 138.

1, 2, 2*a*. *Diploastrea crassolamellata* var. *magnifica* (Duncan) Vaughan.

1. Corallites, natural size, of a specimen from Antigua 477
2. Corallites, natural size; 2*a*, a smaller area, × 2, of a specimen from the base of the Chattahoochee formation near Bainbridge, Georgia. 477

3, 3*a*. *Diploastrea crassolamellata* var. *nugenti* (Duncan) Vaughan. Two views of the same specimen.

3. Corallum, natural size 478
3*a*. Calices, × 2 478

PLATE 139.

1, 1*a*, 1*b*, 2, 2*a*. *Balanophyllia pittieri*, new species.

1. Corallum, natural size; 1*a*, costae, × 4; 1*b*, calice, × 3, of the holotype. 479
2. Corallum, natural size; 2*a*, calice, × 3, of a paratype 479

3, 3*a*. *Astreopora antiguensis*, new species. Two views of the type. Enlarged calices of paratype on plate 140, figure 1.

3. Corallum, one-half natural size 484
3*a*. Part of cross section of lower end, × 3 484

PLATE 140.

1. *Astreopora antiguensis*, new species. Calices of paratype. × 6. For other views see plate 139, figures 3, 3*a* 484

2, 2*a*. *Astreopora portoricensis*, new species. Two views of the type.

2. Corallum, natural size 485
2*a*. Calices, × 6 485

4, 4*a*. *Astreopora goethalsi*, new species.

3. Corallum of a cotype, one-half natural size 483
4. Corallum, one-half natural size; 4*a*, calices, × 6, of the second cotype. 483

PLATE 141.

FIGS. 1, 1*a*, 1*b*, 2. *Acropora panamensis*, new species.
1, 1*a*, 1*b*. Three views of the type. 1, branch, natural size; 1*a*, part of branch, × 3; 1*b*, calice, × 8.
2. View of a paratype, natural size.
3, 3*a*, 4, 4*a*. *Acropora saludensis*, new species.
3. Branch, cotype, natural size; 3*a*, part of the same branch, × 3.
4. Branch, cotype, natural size; 4*a*, part of the same branch, × 3.

PLATE 142.

FIGS. 1, 1*a*. *Goniopora hilli*, new species. Two views of the type.
1. Surface of corallum, natural size.
1*a*. Calices, × 6.
2, 2*a*, 2*b*. *Goniopora panamensis*, new species. Three views of the type.
2. One surface, natural size.
2*a*. The other surface, natural size.
2*b*. A part of the surface represented by figure 2*a*, × 3.
3, 3*a*. *Goniopora imperatoris*, new species. Two views of the type.
3. Corallum, natural size.
3*a*. Calices, × 6.

PLATE 143.

FIGS. 1, 1*a*. *Goniopora decaturensis*, new species. Two views of the type.
1. Upper surface, natural size.
1*a*. Calices, × 3.
2, 2*a*. *Goniopora decaturensis* var. *silecensis*, new variety. Two views of the type.
2. Corallum, natural size.
2*a*. Calices, × 3.
3, 3*a*. *Goniopora decaturensis* var. *bainbridgensis*, new variety. Two views of the type.
3. Corallum, natural size.
3*a*. Calices, × 3.

PLATE 144.

Goniopora jacobiana, new species.

FIG. 1, 1*a*. Two views of type.
1. Corallum, one-half natural size.
1*a*. Calices, × 6. The thick, white radii represent interseptal filling; the septa have been dissolved and are represented by the black space.
2, 2*a*, 3, 3*a*. Four views of two fragments of the same specimen from White Springs, Florida.
2. Upper surface, natural size; 2*a*, calices, × 6, of the same fragment.
3. Upper surface, natural size; 3*a*, calices, × 4, of the same fragment.

PLATE 145.

Goniopora clevei, new species.

FIG. 1. Paratype, natural size, University of Upsala.
2, 2*a*. Two views the type, also University of Upsala.
2. Branch, natural size.
2*a*. Calices, × 5.
3. Paratype, natural size. An elongate branch, tip rounded.
4. Paratype, natural size. A thicker branch; tips of branchlets obtuse rounded.

5, 5*a*. Two views of a specimen somewhat flattened by pressure. Page.
5. Natural size ... 497
5*a*. Calices, × 6 ... 497
(Originals of figures 1–5*a* from Anguilla.)
6, 6*a*. Two views of a specimen somewhat flattened by pressure, from Empire, Canal Zone.
6. Natural size ... 497
6*a*. Calices, × 6 ... 497

PLATE 146.

1, 2, 3. *Goniopora canalis*, new species.
1. Cotype, corallum, natural size ... 494
2. Second cotype, corallum, natural size ... 494
3. Third cotype, calices, × 6 ... 494
4, 5. *Goniopora portoricensis*, new species.
4. Type, corallum, natural size ... 495
5. Calices, × 6, of a paratype ... 495
6, 6*a*, 6*b*, 7, 8, 9. *Goniopora cascadensis*, new species.
6. Type, natural size; 6*a* and 6*b*, calices, × 6 ... 497
7. Paratype, natural size ... 497
8. Paratype, natural size ... 497
9. Calices of a third paratype, × 6 ... 497

PLATE 147.

1, 1*a*. *Porites baracoäensis*, new species. Two views of the type.
1. Branch, natural size ... 499
1*a*. Part of branch, × 5 ... 499
2, 2*a*, 3, 4. *Porites baracoäensis* var. *matazasensis*, new variety.
2. Type, corallum, natural size; 2*a*, the same, × 5 ... 500
3. Paratype, × 5 ... 500
4. Paratype, × 5, shows intergradation with the typical form of the species ... 500

PLATE 148.

Porites panamensis, new species.

Paratype corallum, natural size ... 504
Calices, × 8, of a paratype ... 504
3*a*. Two views of the type.
3. Corallum, natural size ... 503
3*a*. Calices, ×8 ... 503

PLATE 149.

1*a*, 1*b*. *Porites anguillensis*, new species. Three views of the type.
1. Upper surface, natural size ... 504
1*a*. Lower surface, natural size ... 504
1*b*. Calices, × 5 ... 504
2*a*. *Porites douvillei*, new species. Two views of a cotype.
2. Branch, natural size ... 501
2*a*. Calices, × 8 ... 501
3*a*. *Actinacis alabamiensis* (Vaughan). Two views of a small specimen from Flint River, near Bainbridge, Georgia.
3. Corallum, natural size ... 486
3*a*. Calices, × 5 ... 486

PLATE 150.

FIGS. 1, 1*a*, 2, 3, 4. *Porites toulai*, new species.
1, 1*a*. Type, natural size; 1*a*, calices, × 8, of the type
2. Paratype, natural size
3. Second paratype, natural size
4. Calices of a third paratype, × 8
5. *Porites anguillensis*, new species. Specimen from Empire, Canal Zone, natural size

PLATE 151.

FIGS. 1, 1*a*. *Porites douvillei*, new species. Two views of a cotype.
1. Corallum, natural size
1*a*. Calices, × 8
2, 2*a*, 3, 3*a*, 4. *Porites* (*Synaraea*) *howei*, new species. Views of the three cotypes.
2. Branch, natural size; 2*a*, part of the same branch, × 3
3, 3*a*. Two views, natural size, of the same branch
4. Calices, × 8, of a third branch

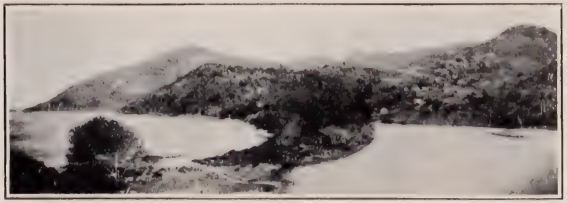
PLATE 152.

Porites (*Synaraea*) *macdonaldi*, new species.

FIG. 1. A cotype, natural size
2. A second cotype, natural size
3, 3*a*. Two views of a third cotype.
3. Natural size
3*a*. Part of surface, × 3
4. A fourth cotype, natural size
5, 5*a*. Two views of a specimen referred to this species.
5. Corallum, natural size
5*a*. A calice, × 8

A. Five Islands Harbor, Antigua.

B. Spencer Bay, Antigua.



C. Publiken Bay, St. Bartholomew.

D. St. Jean Bay, St. Bartholomew.

WEST INDIAN SHORE LINES.

For explanation of plate see page 607.

A. Pointe Blanche, St. Martin.

B. East Side of Crocus Bay, North Side of Anguilla.

C. Calls Pond, Anguilla.

D. Shore, South Side of Aguilla, Looking Toward St. Martin.

WEST INDIAN SHORE LINES.

A. Looking into the Mouth of Charlotte Amalia Harbor, St. Thomas.

B. Cliffs on Southern Shore of St. Thomas.

C. Alluvial Plain at Head of an Embayment, St. Thomas.

D. Mountains on North, Limestone Plain on South, St. Croix.

WEST INDIAN SHORE LINES.

For explanation of plate see page 508

A. SANTIAGO HARBOR, CUBA, LOOKING INTO THE HARBOR; SLIGHTLY ELEVATED CORAL REEF ROCK IN LEFT FOREGROUND.

B. SANTIAGO HARBOR, CUBA, LOOKING SEAWARD THROUGH ITS MOUTH.

C. YUMURI GORGE, MATANZAS, CUBA.

D. YUMURI VALLEY ABOVE THE GORGE.

WEST INDIAN SHORE LINES.

FOR EXPLANATION OF PLATE SEE PAGE 508.

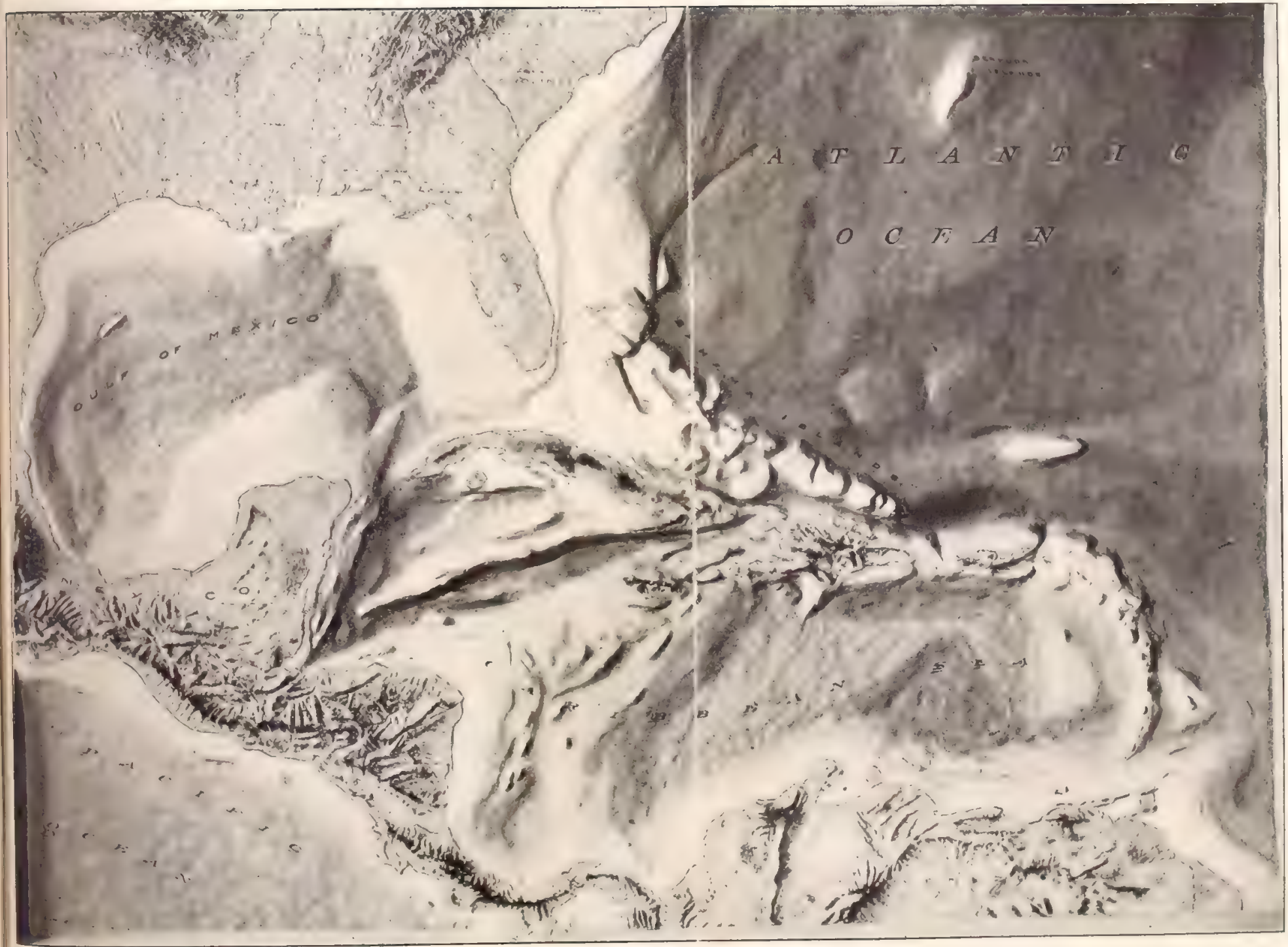
A. THE GENERAL PLAIN.

B. DAGUILLA, A MONADNOCK OF HARD ROCK.

C. LOWER PART OF COURSE OF SANTA FE RIVER.

VIEWS OF ISLE OF PINES, CUBA.

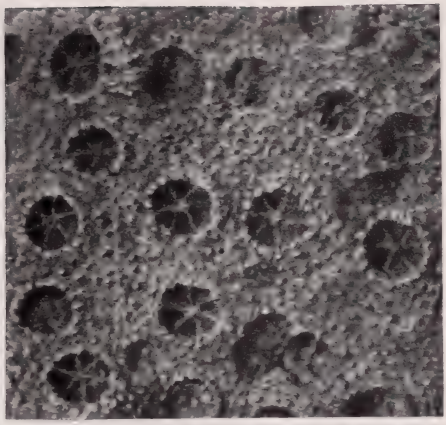
FOR EXPLANATION OF PLATE SEE PAGE 508.



MODEL OF GULF OF MEXICO AND CARIBBEAN SEA.

FOR EXPLANATION OF PLATE SEE PAGE 508

1



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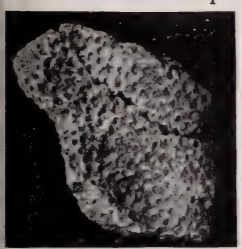

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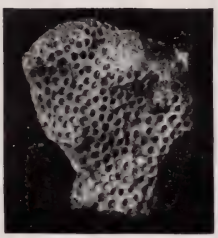

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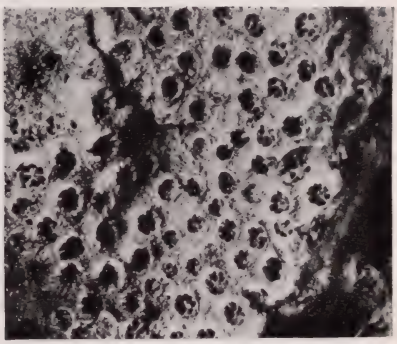

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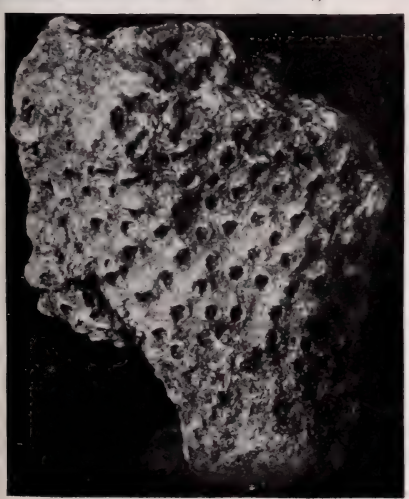


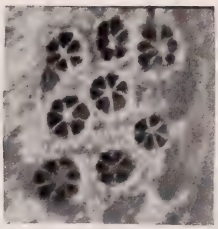
2 × 3

4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 508.

1



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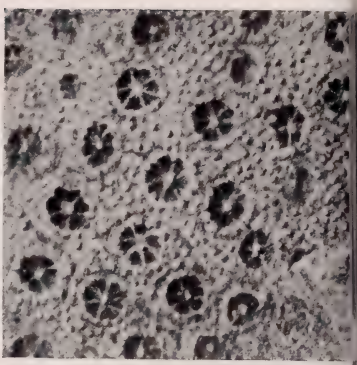

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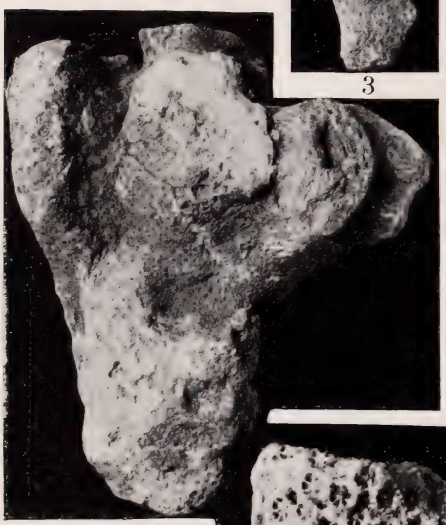

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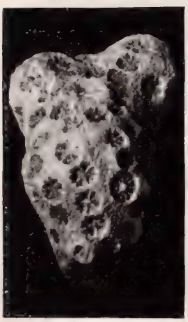


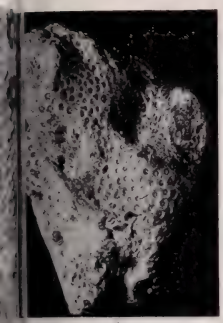
5a X 3

6a X 3

7a X 8

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 508.



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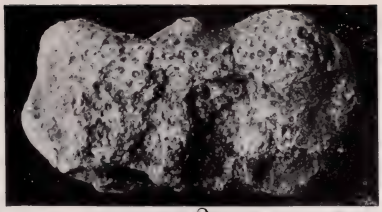

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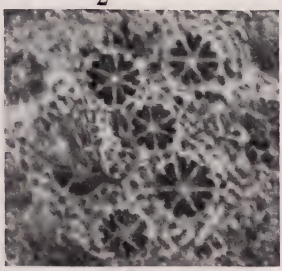

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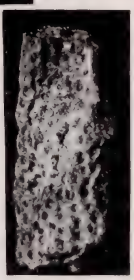

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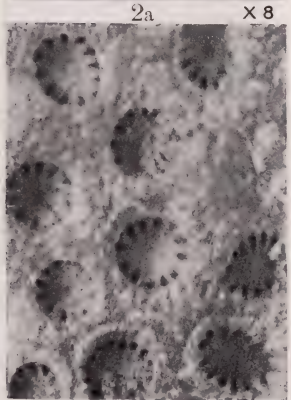

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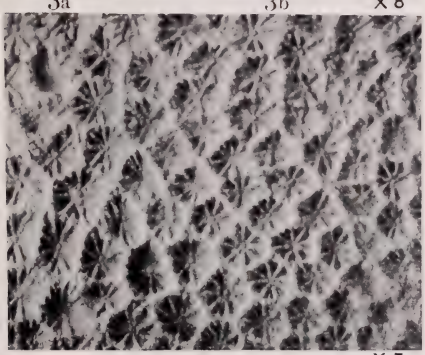
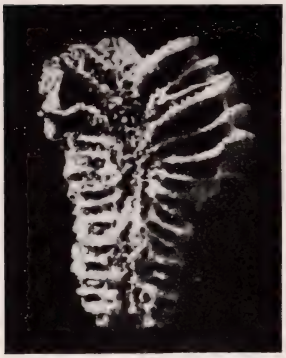


4a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 509.

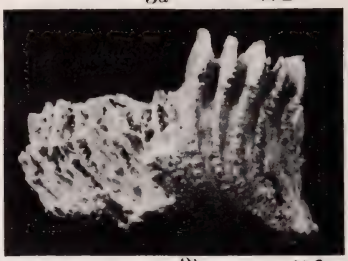


3 X 2

3a X 2

1

2



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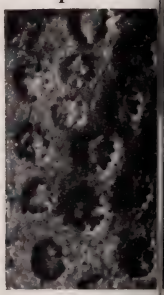

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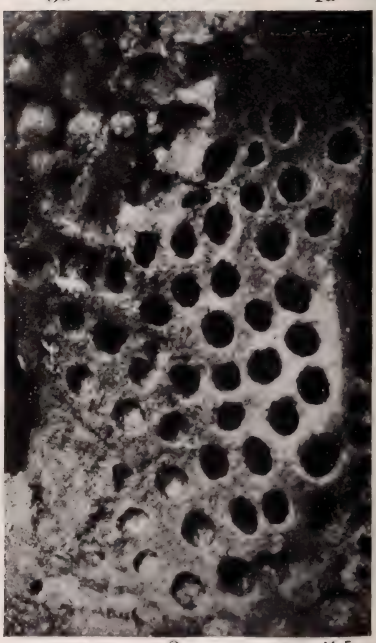
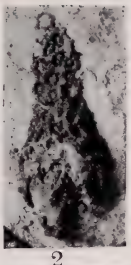


2a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 509.

1



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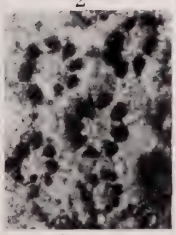

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1a X 5

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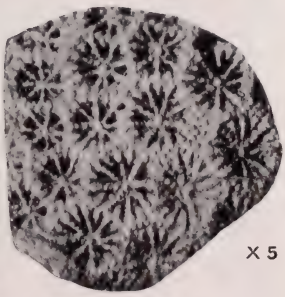

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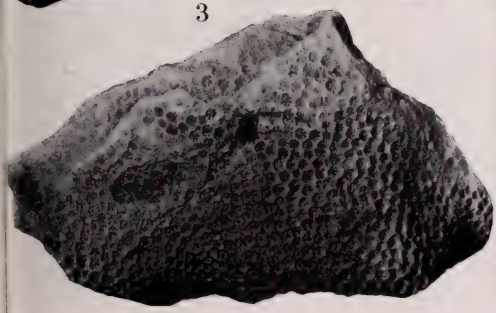

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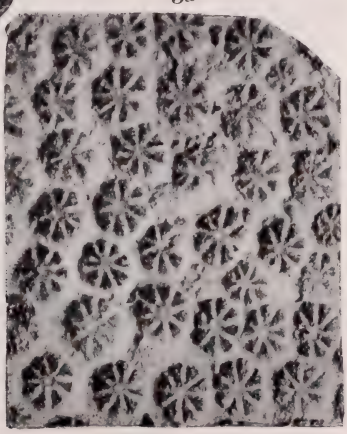


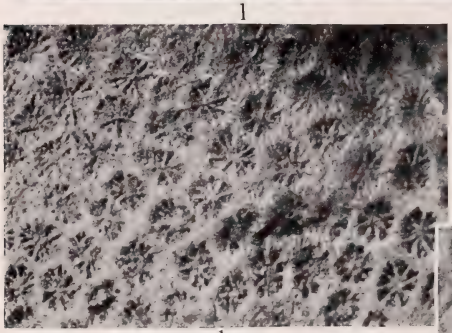
4a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 509.

1

3



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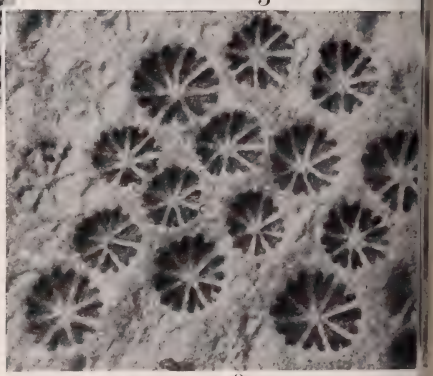
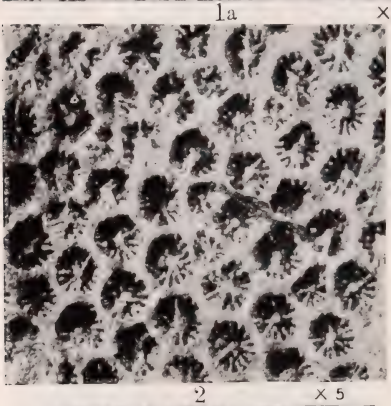
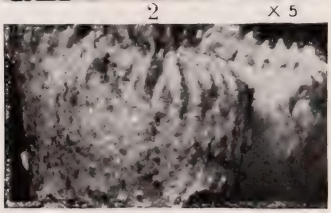


3a X



2 X 5



4a X 4

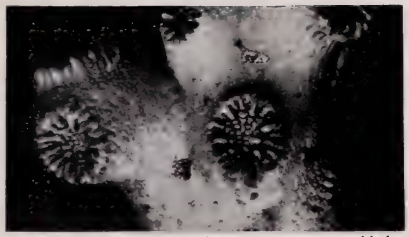
4

4b X

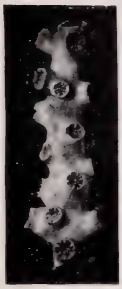
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 539.

1



1a X 4



2

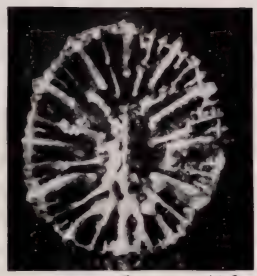
3

4 X 2

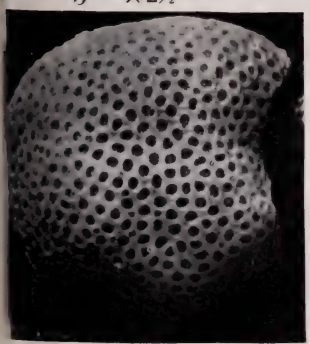
1b X 4

6 X 2½

5 X 2½



6a X 3



7 X ⅝

7a X 3⅓

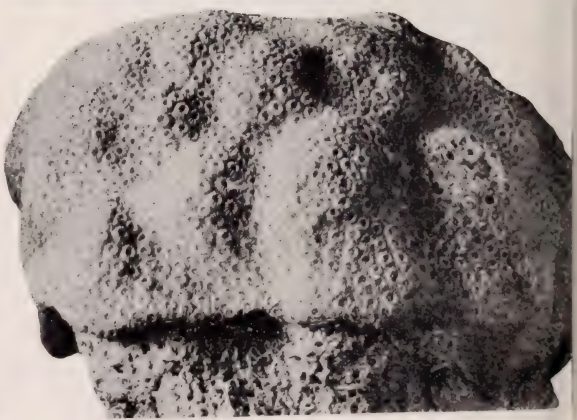
7b X 3⅓

FOSSIL CORALS FROM CENRTAL AMERICA AND WEST INDIES

FOR EXPLANATION OF PLATE SEE PAGE 510.

1

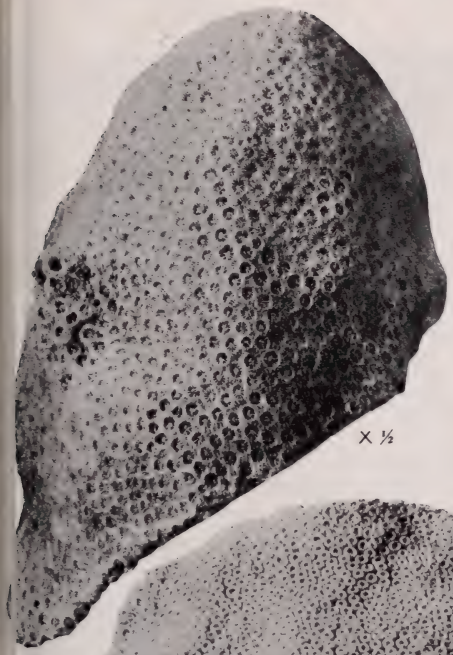
1a X 3



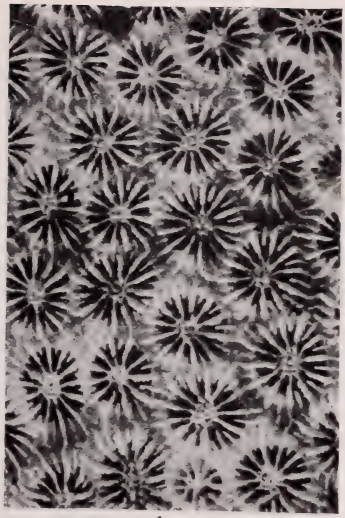
2 X 2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 510.



X ½



1a X 3

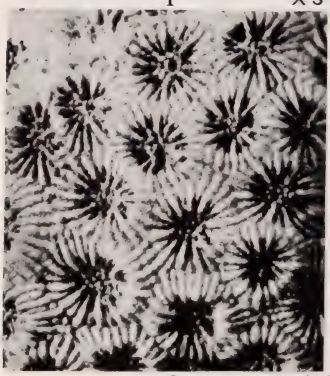
X ½

2

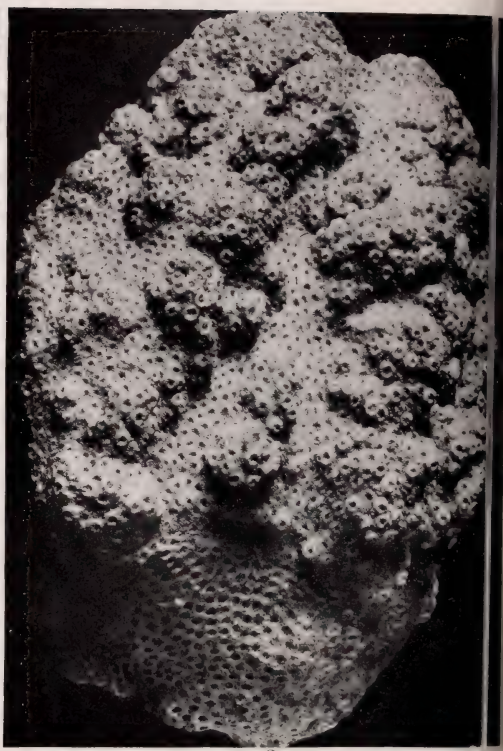
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 510.

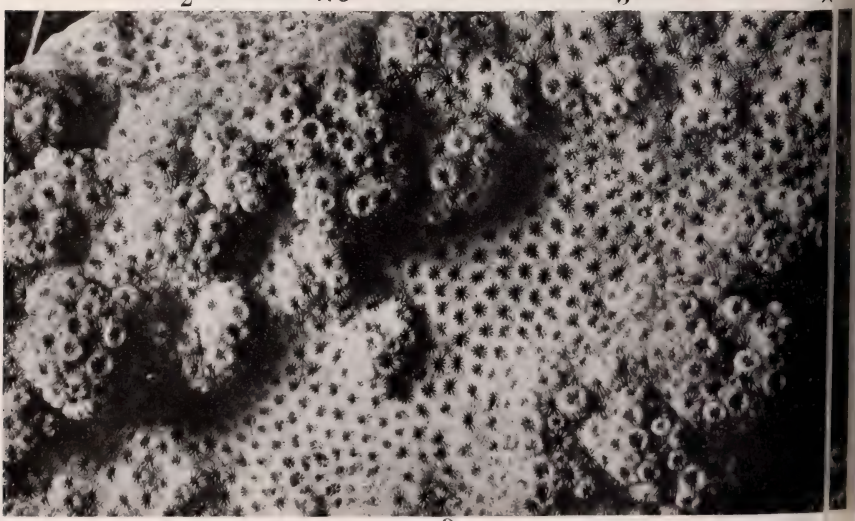
1 X 3



2 X 3



3 X



3a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 510.

1 X 3

3a X 3

3

2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 510.

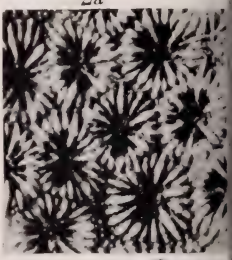
1

1a × 3

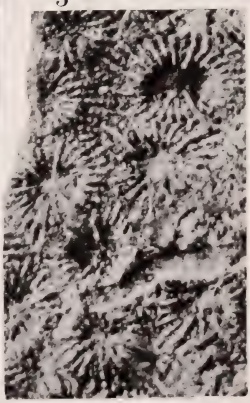
2a

2

3 × 3



2b

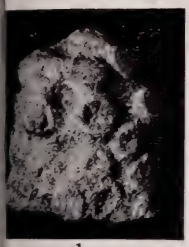


4a × 3

4

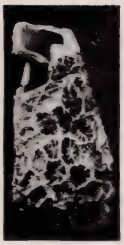
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 511.

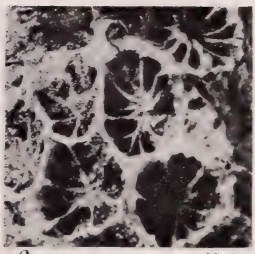


1

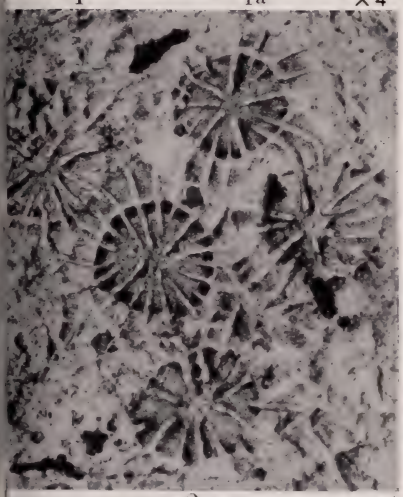
1a X 4



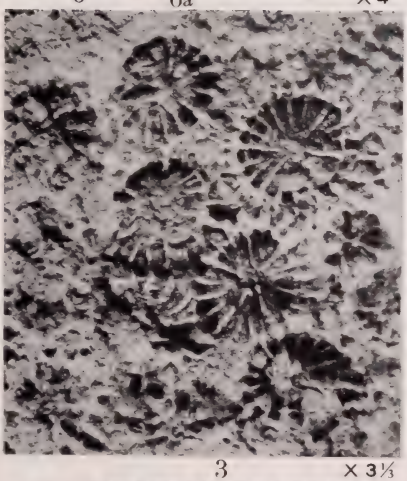
6



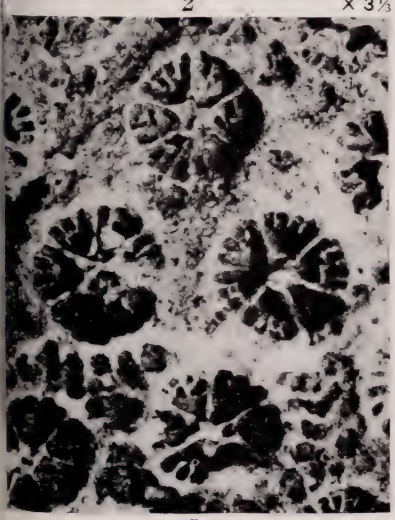
6a X 4



2 X 3⅓



3 X 3⅓

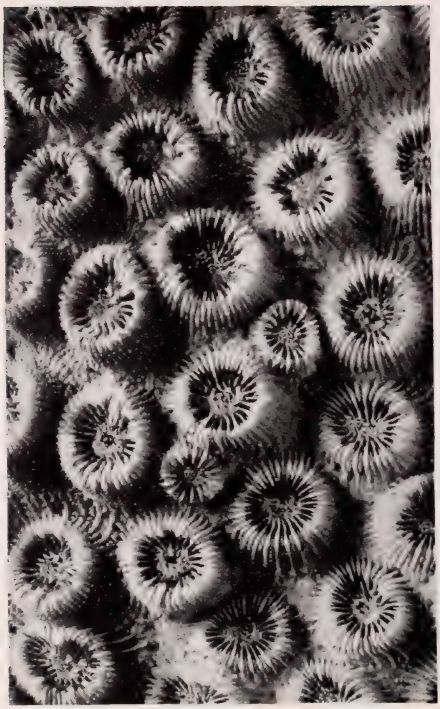


5 X 3⅓

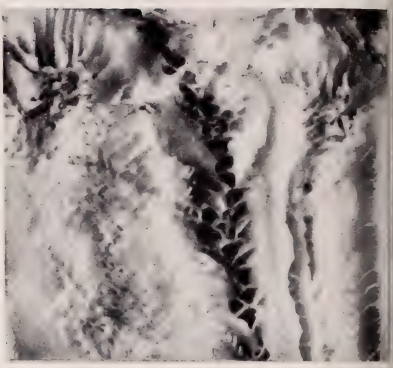
4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 511.

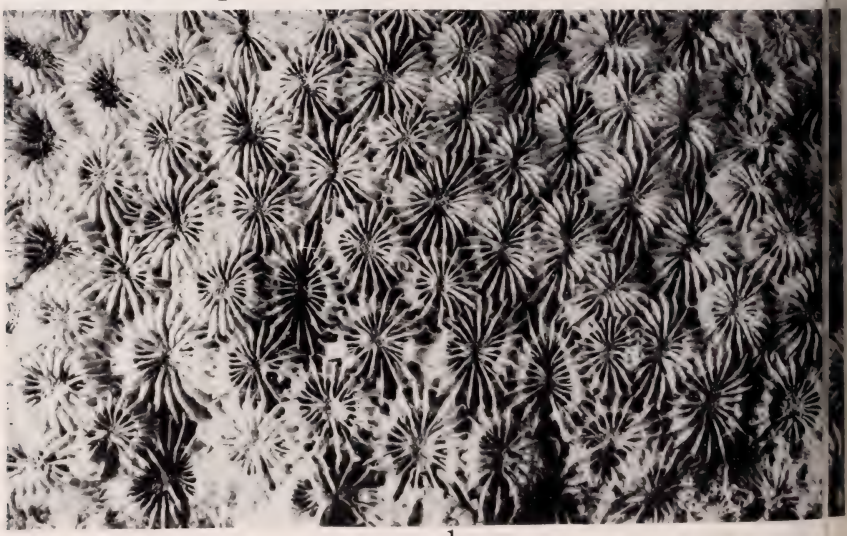


1



1b X

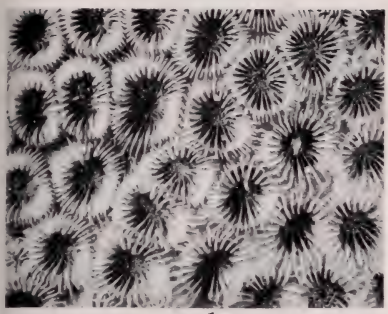
1c X



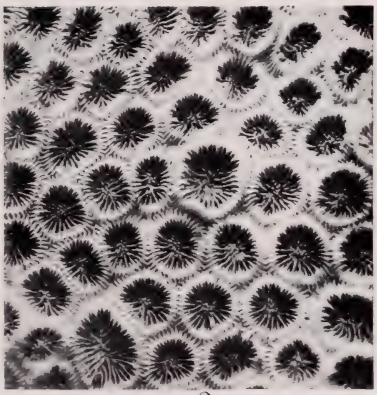
1a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

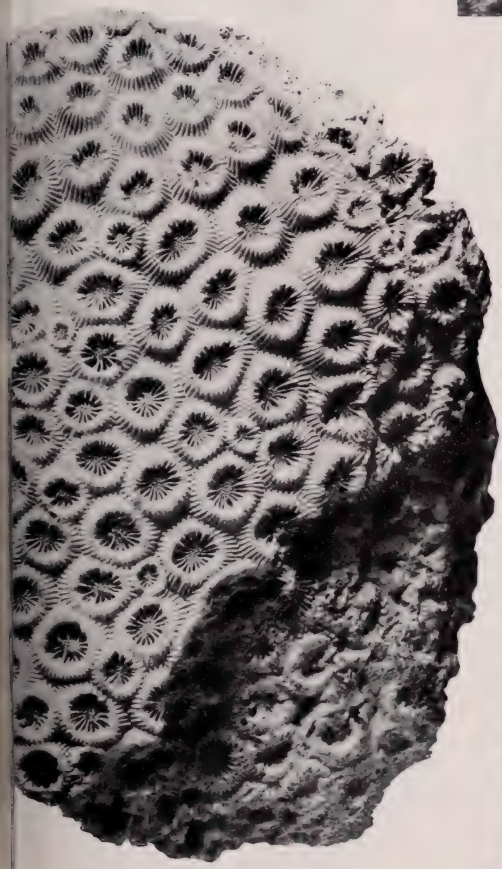
FOR EXPLANATION OF PLATE SEE PAGE 511.



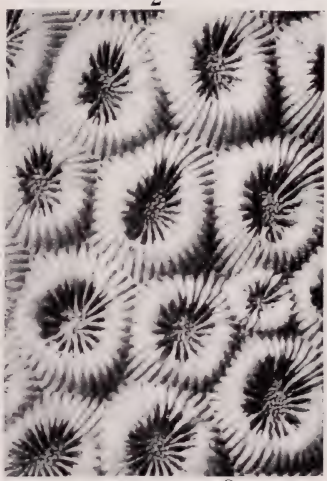
1



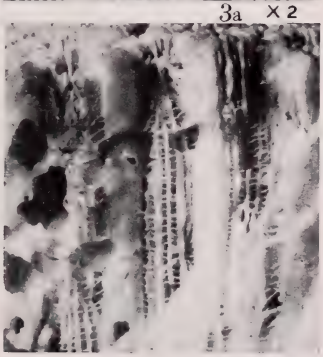
2



3



3a X 2



3b X 2

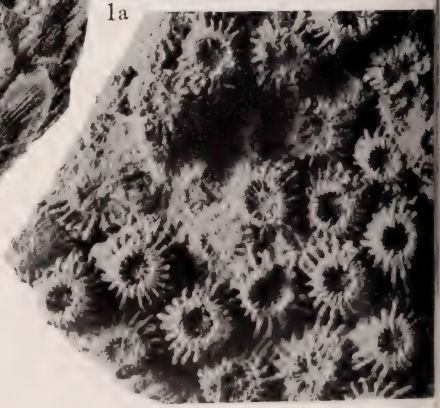
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 511.

3

1a

1

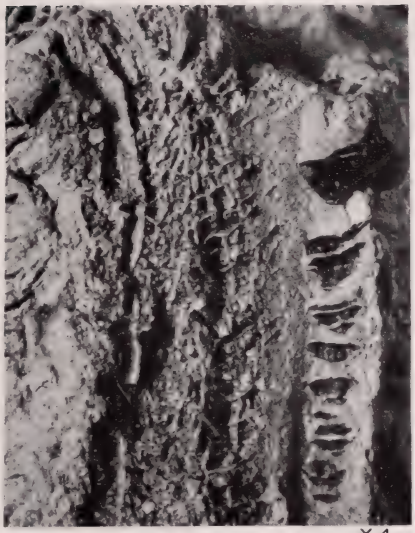


2

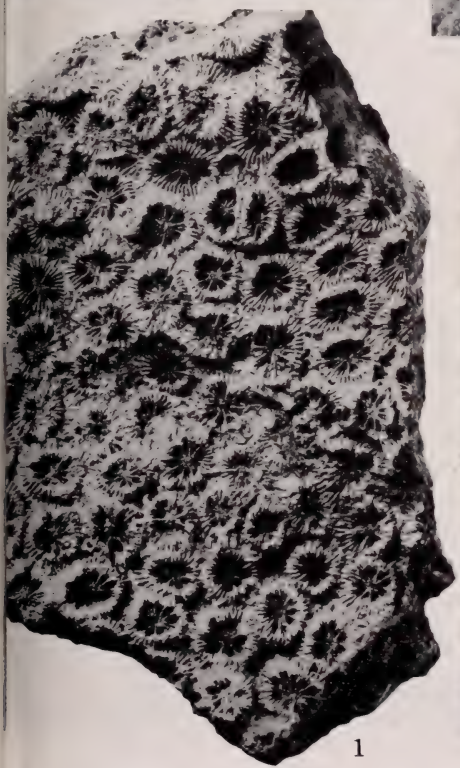
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 512.

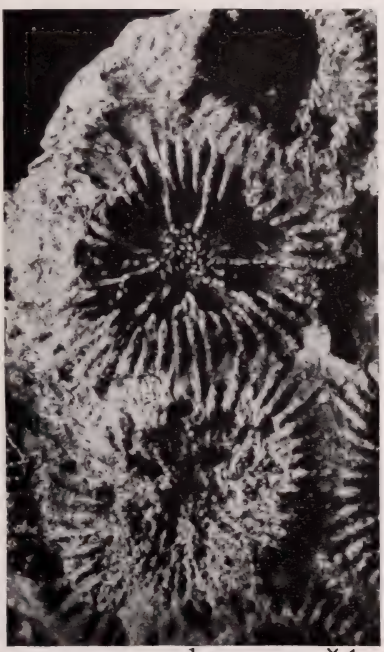
1c X4



1b X4



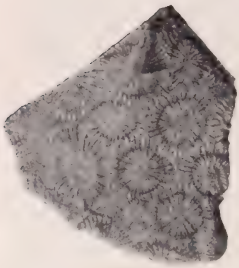
1



1a X4

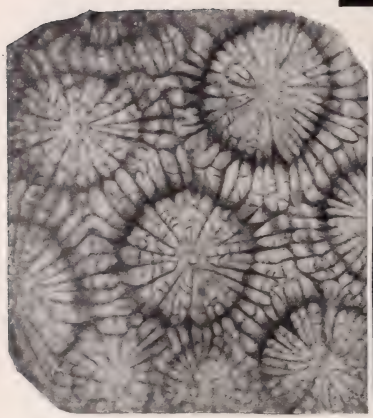
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 512.

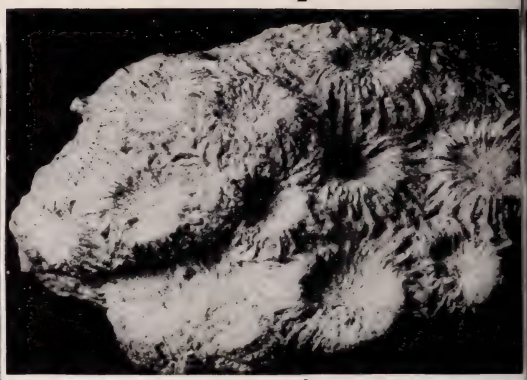


1

2



1a X 3



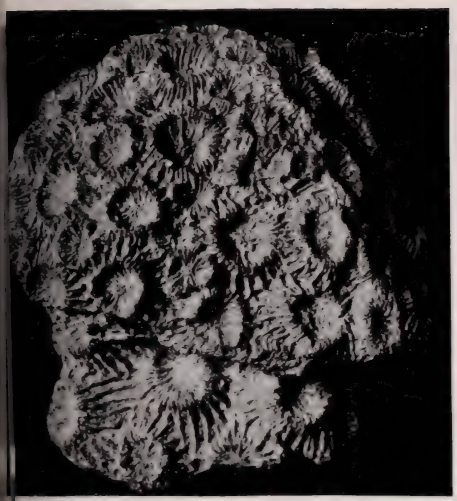
3

3a

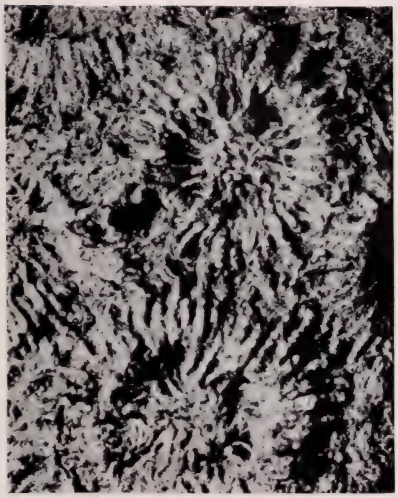
4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

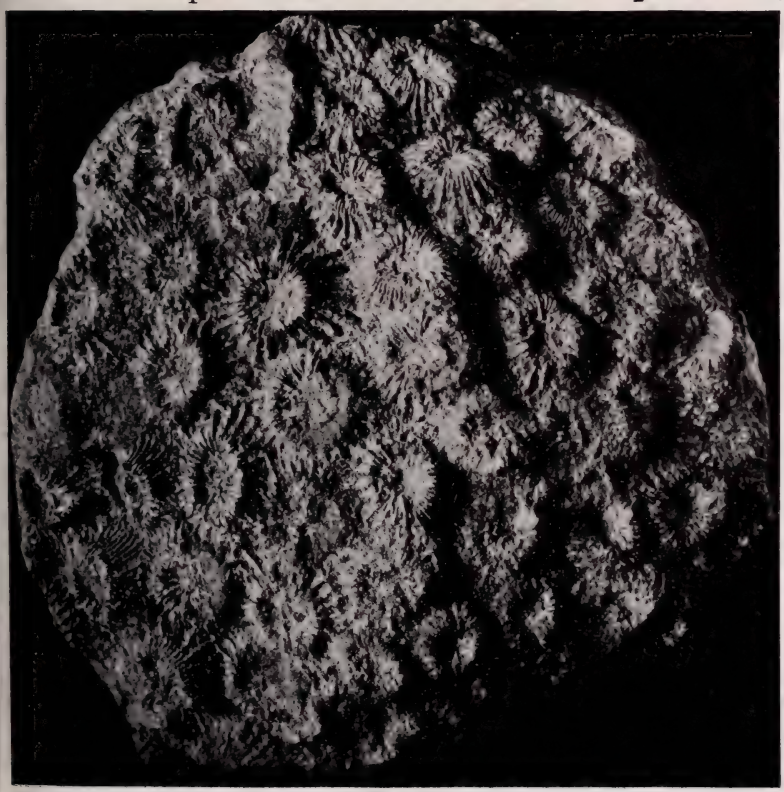
FOR EXPLANATION OF PLATE SEE PAGE 512



1



2 X 4

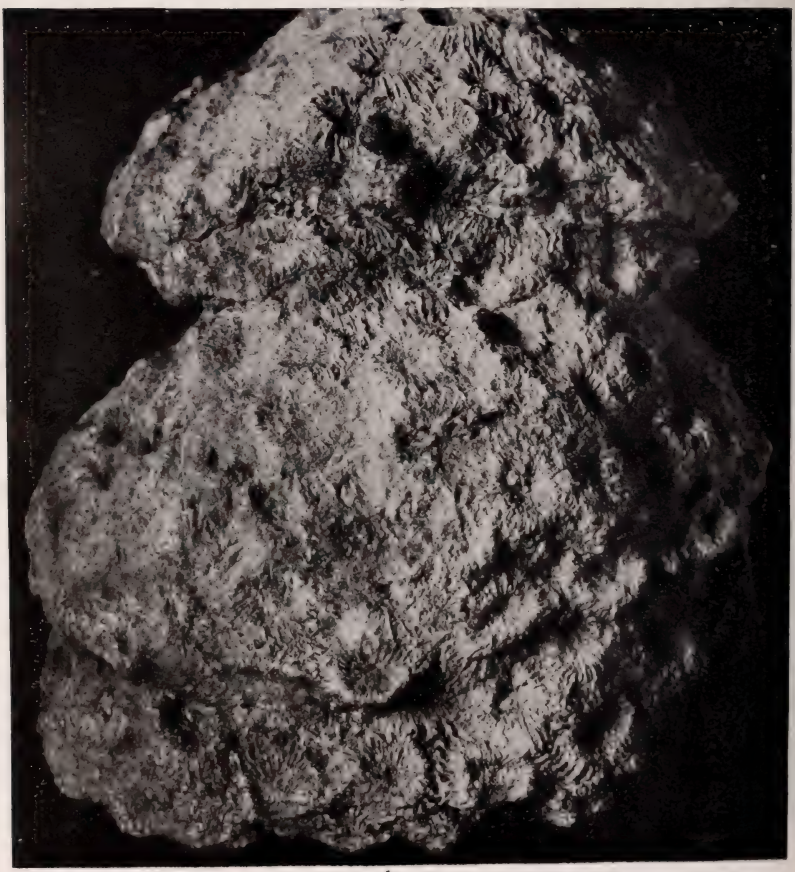


3

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 12.

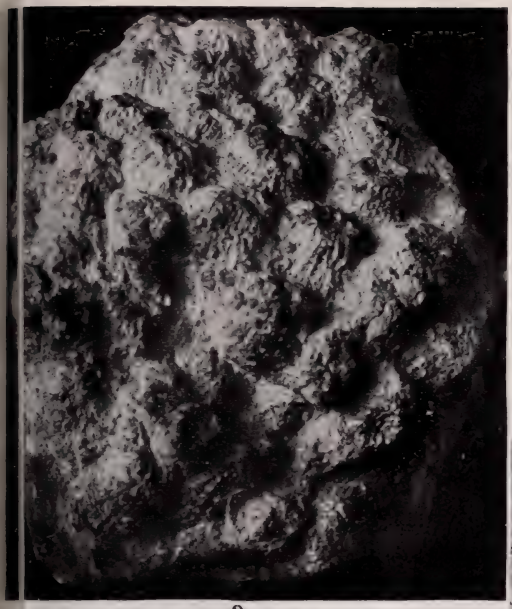
1 X 4



1a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

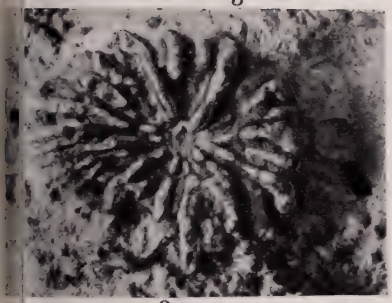
FOR EXPLANATION OF PLATE SEE PAGE 512.



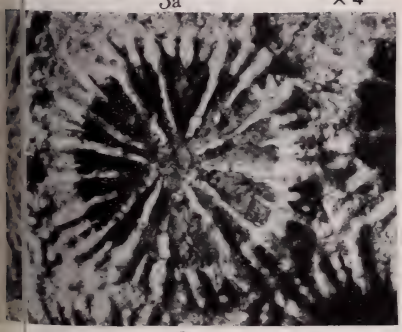
3

1

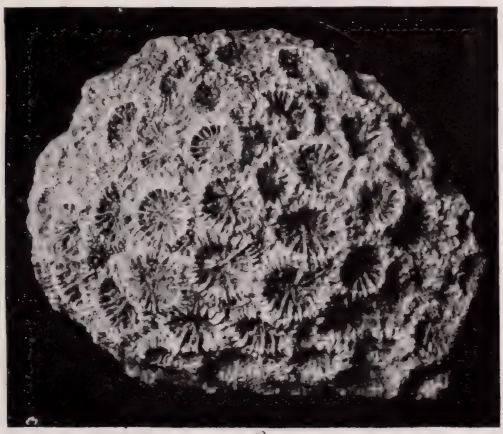
1a X 4



3a X 4



2a X 4

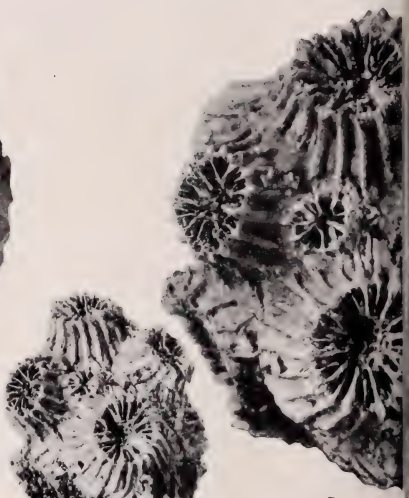


2

Fossil Corals from Central America and West Indies.

For explanation of plate see page 512.

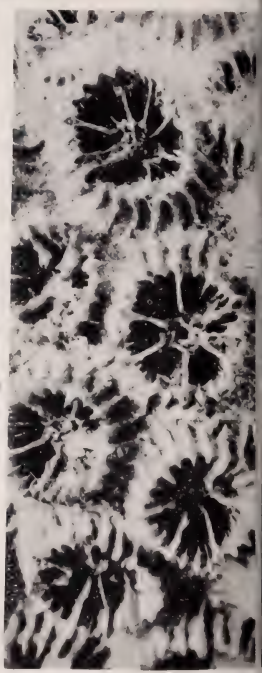
1



2a

2

3



3a

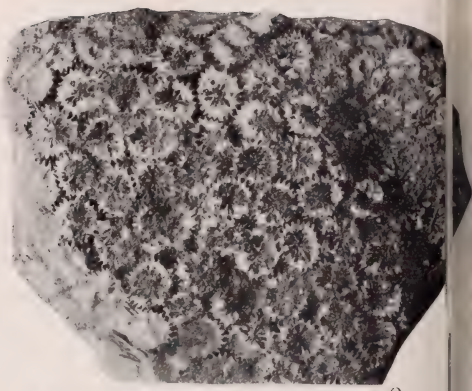
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 513.

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 513.

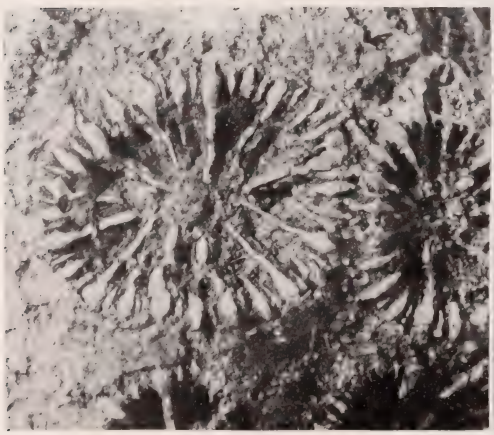
1



2

3

3a

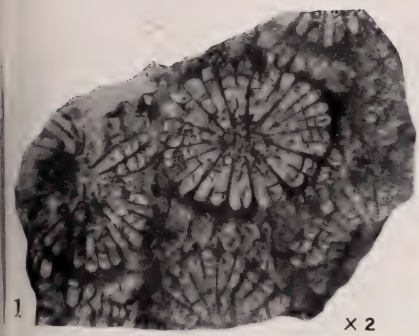


4 X 4

4a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 513.

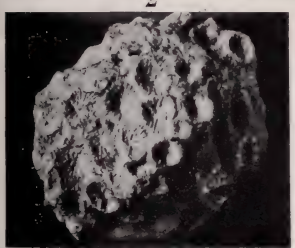


1 X 2

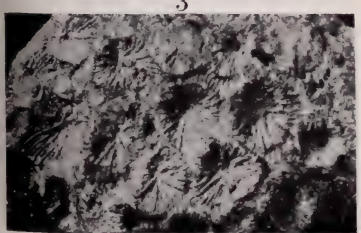
2a X 2

2 X 2

4a X 2



3



3a X 2

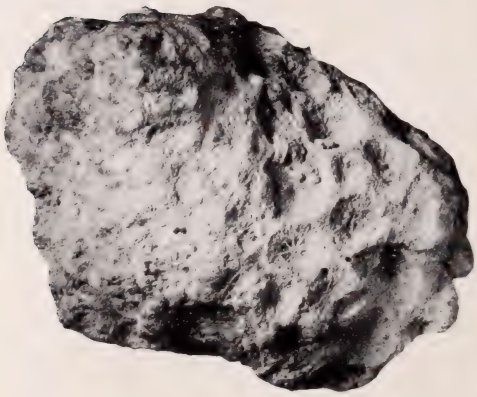
4 X 2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 513.

1

1a



2

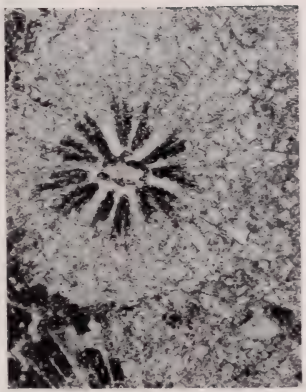
2a

3

3a

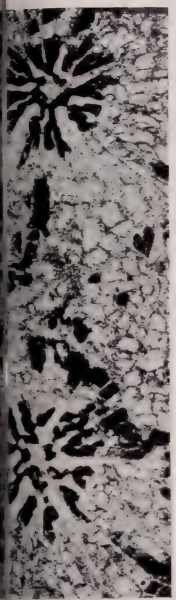
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 513.



1 × 6

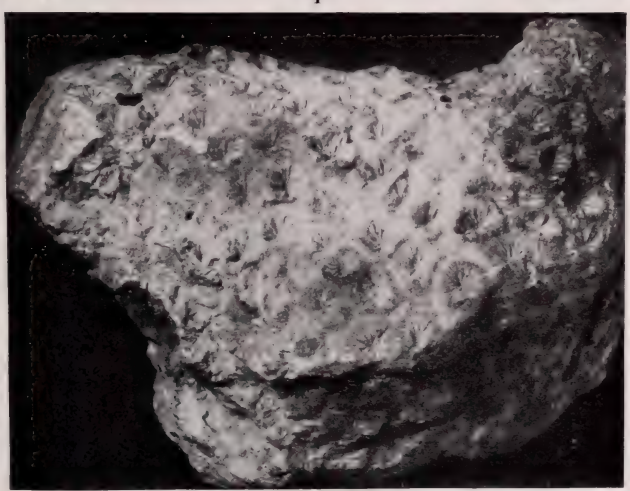
4a × 4



2 × 6

4

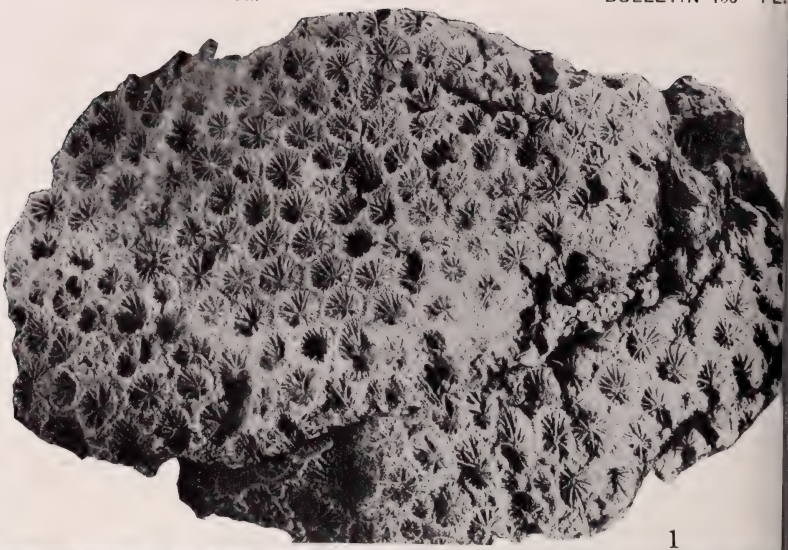
3a × 6



3

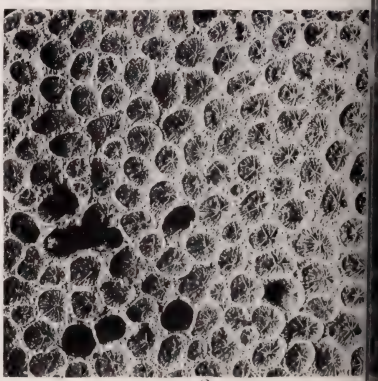
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 514.

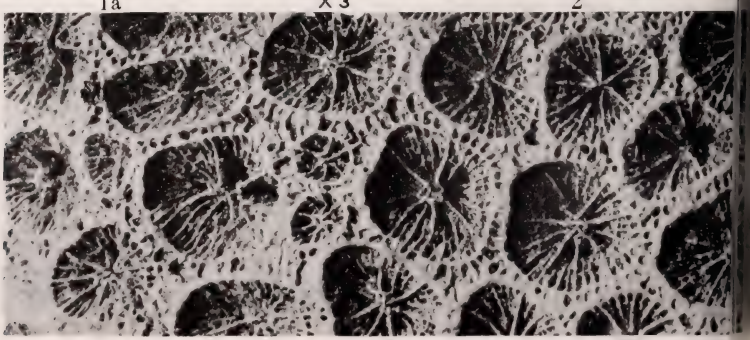


1

1a X 3



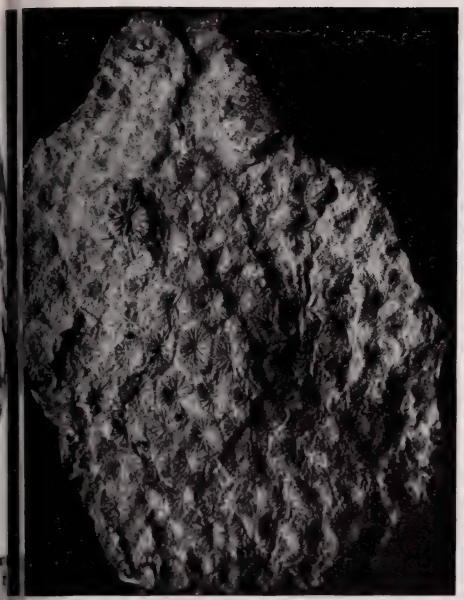
2



2a X

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 514.



1

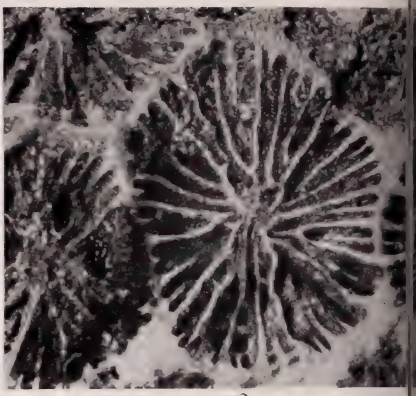
1a X 4

2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 514.

1 X 2



2a

2

3

4

4a

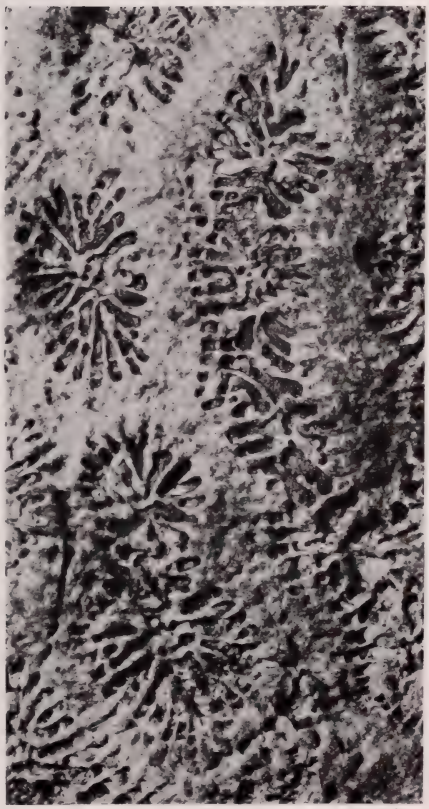
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 514.

1

2a × 2

2



1a × 4

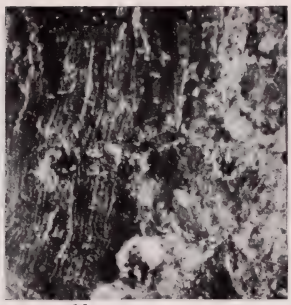
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 514.

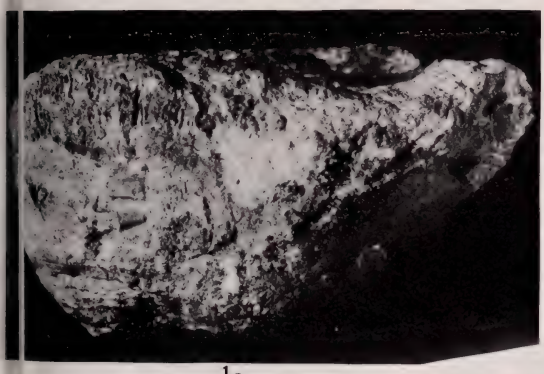
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 515.

1

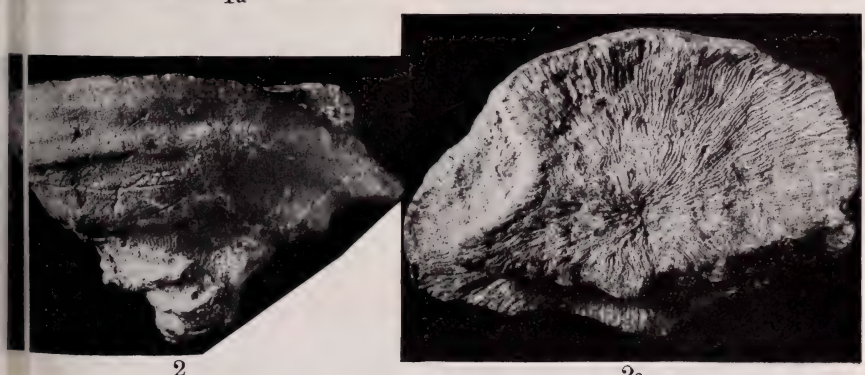


1b X 5



1a

2b X 5



2 2a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

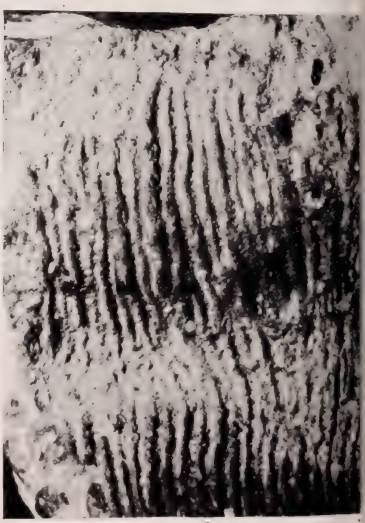
FOR EXPLANATION OF PLATE SEE PAGE 515.

1

1a

2

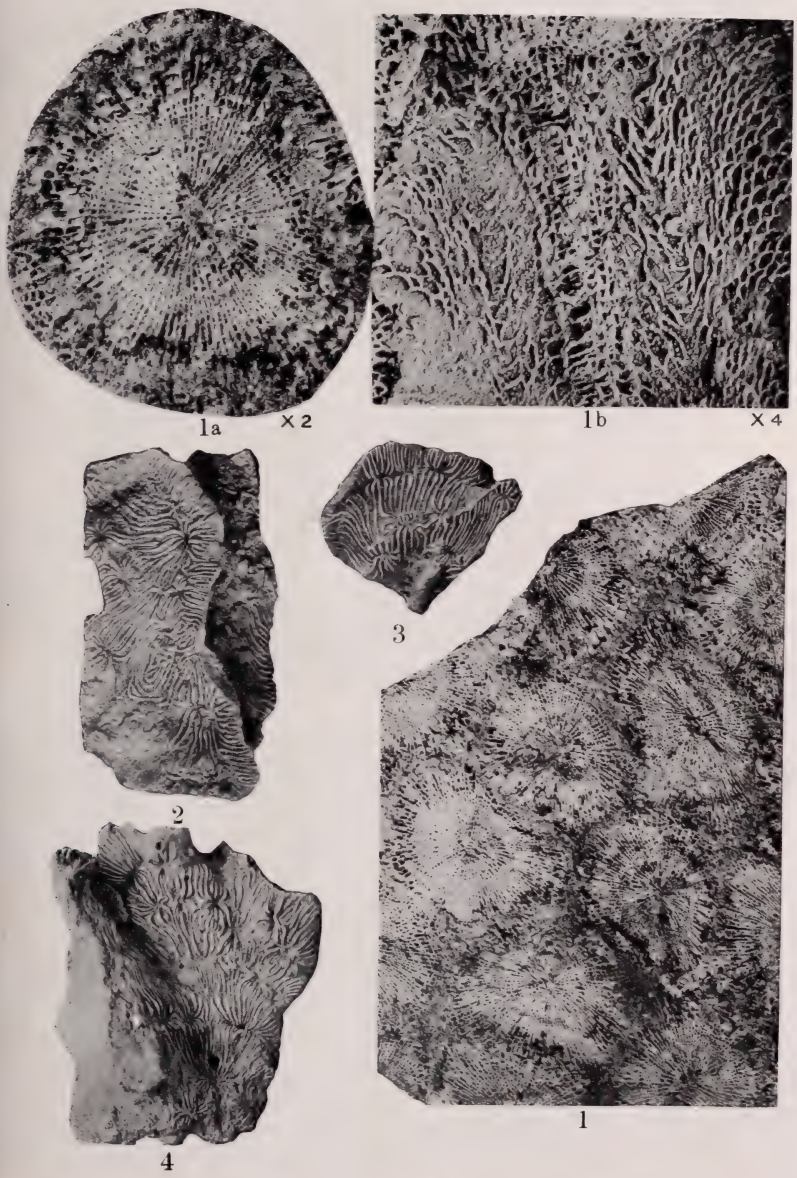
2a



2b

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

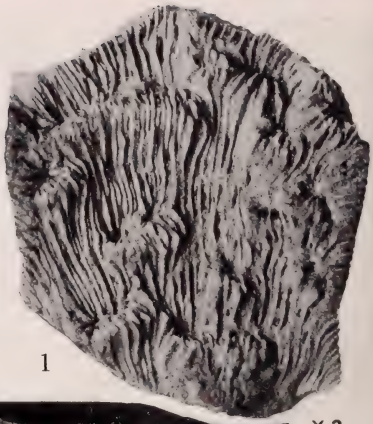
FOR EXPLANATION OF PLATE SEE PAGE 515.



FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 515.

1a X 2



1 X 2

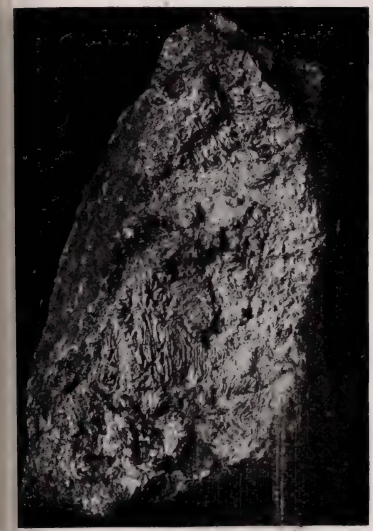
2a X 2

2

3

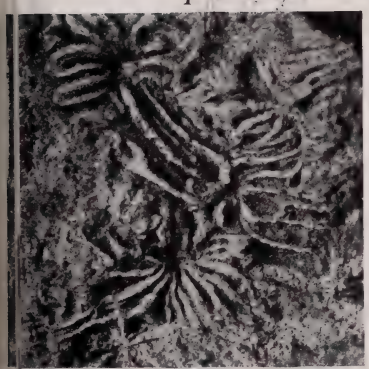
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 515.



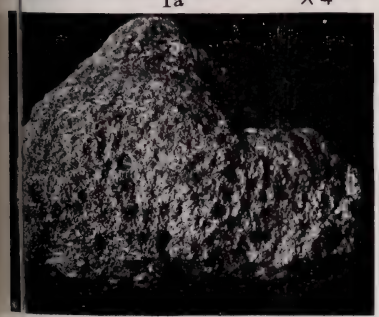
1

1b X 4



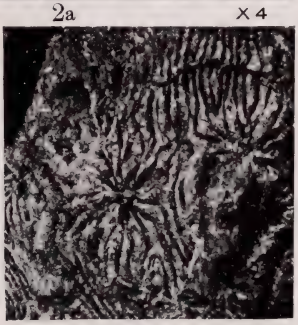
1a X 4

2a X 4



2

3

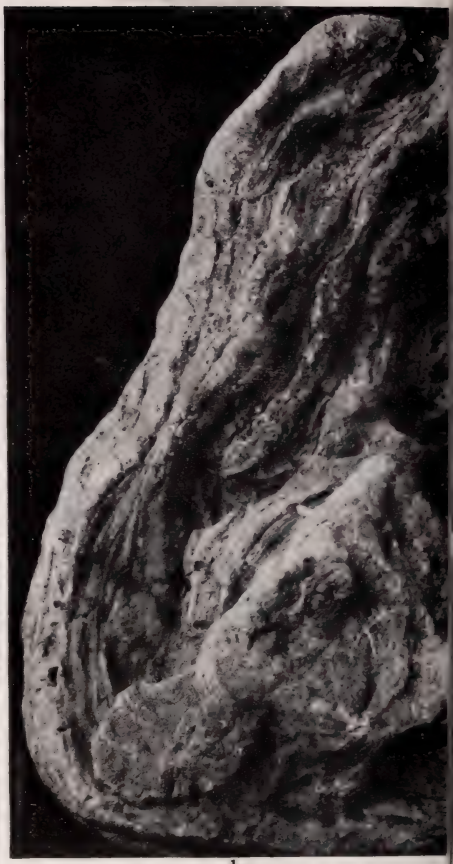


3a X 4

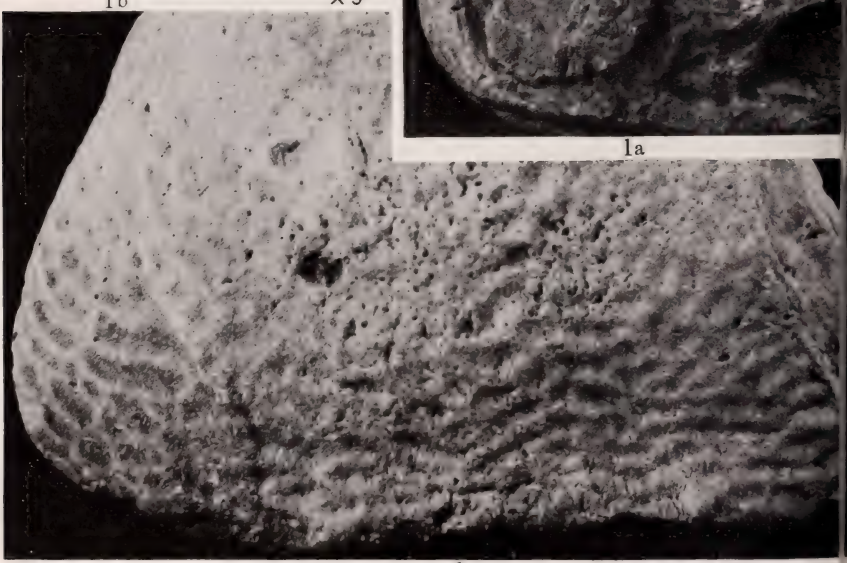
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGES 515 AND 516.

1b X 5



1a



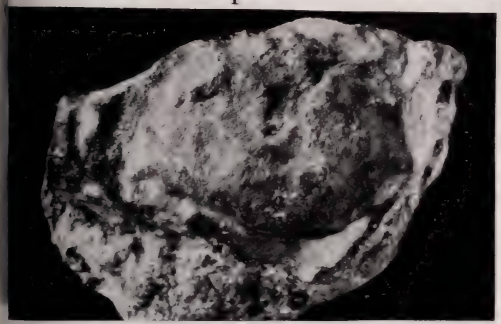
1

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 516.

1

1a X 5



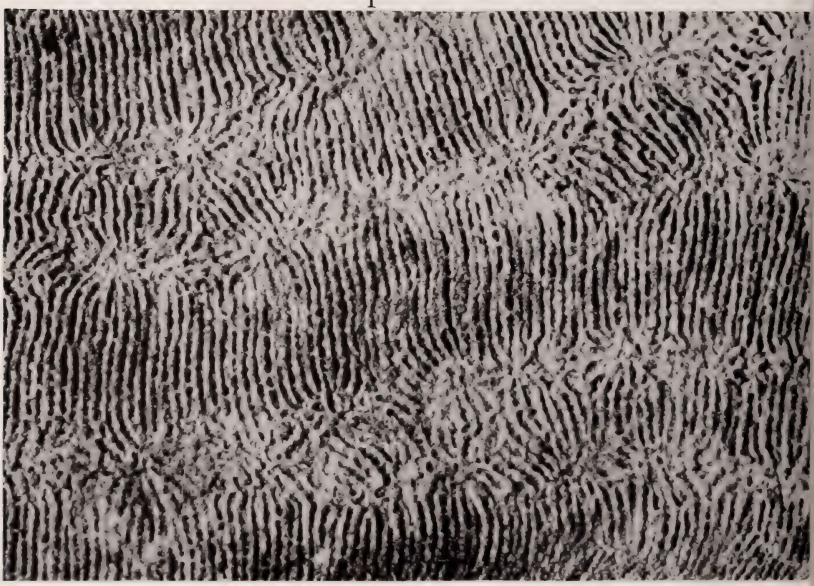
2

2a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 516.

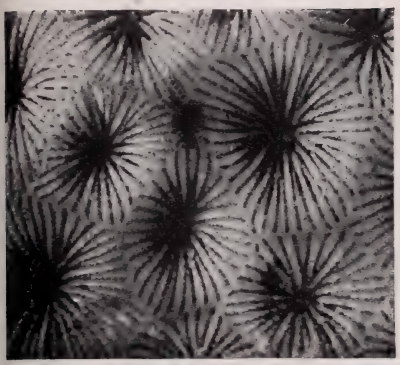
1



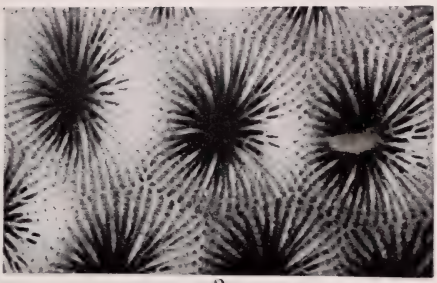
1a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

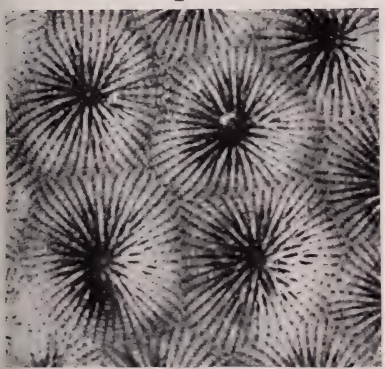
FOR EXPLANATION OF PLATE SEE PAGE 516.



1 ×6

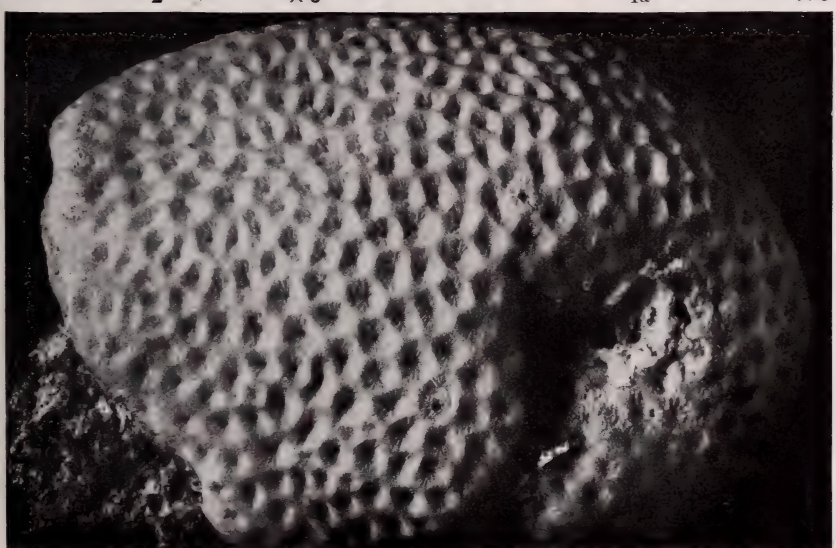


3 ×6



2 ×6

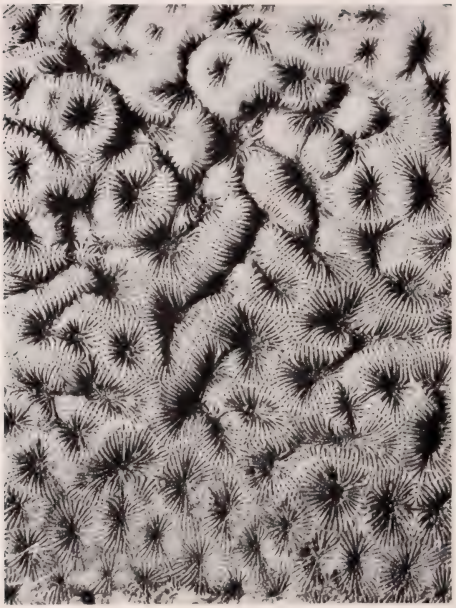
4a ×6



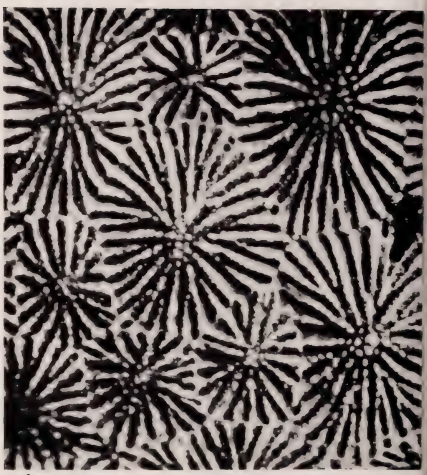
4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.



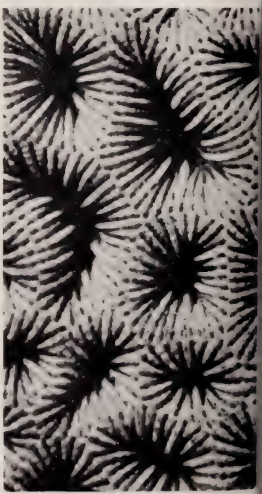
2a X 2



1a X 6

1

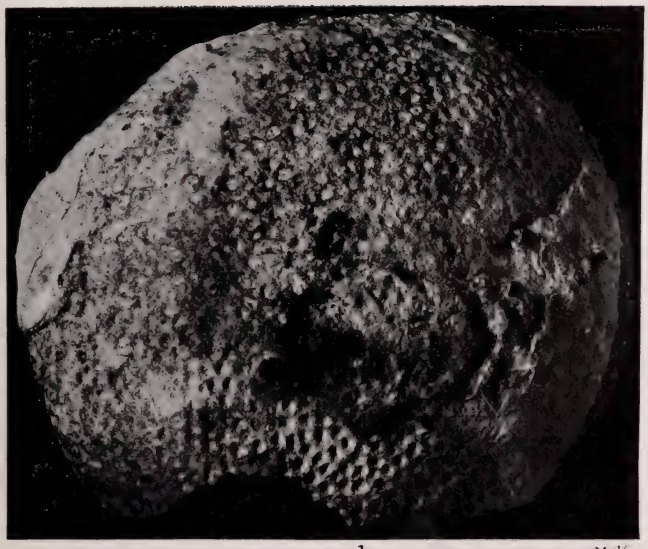
2 X ½



2b X 6

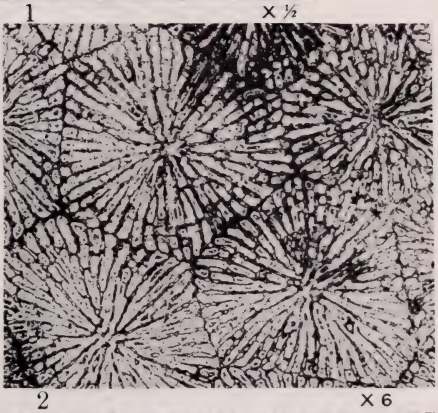
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 516.

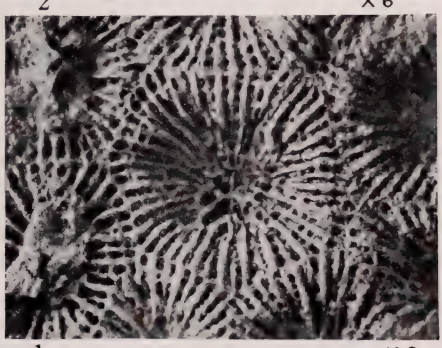


1 X ½

3 X 6



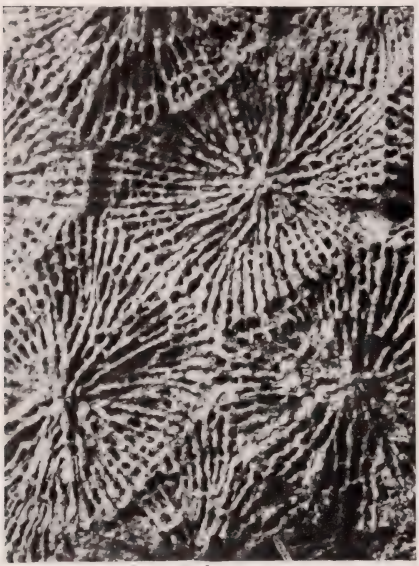
2 X 6



1a X 6

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 517.



1 X 6

1b

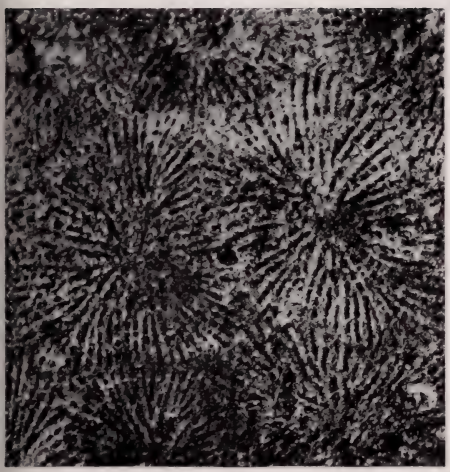
1a X 6

2

3

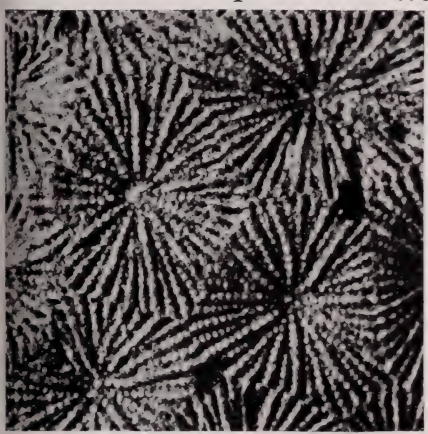
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 517.

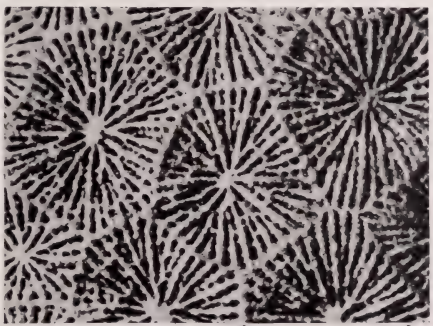


1 X 6

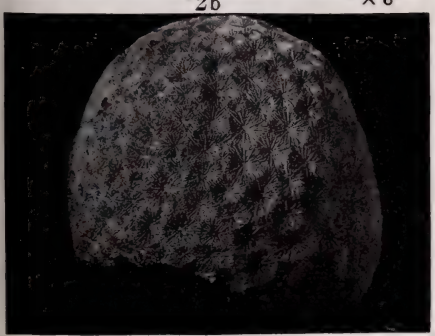
1a X 6



2b X 6



3 X 6

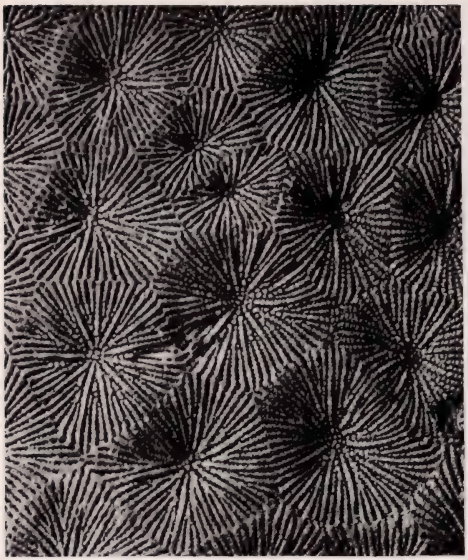


2

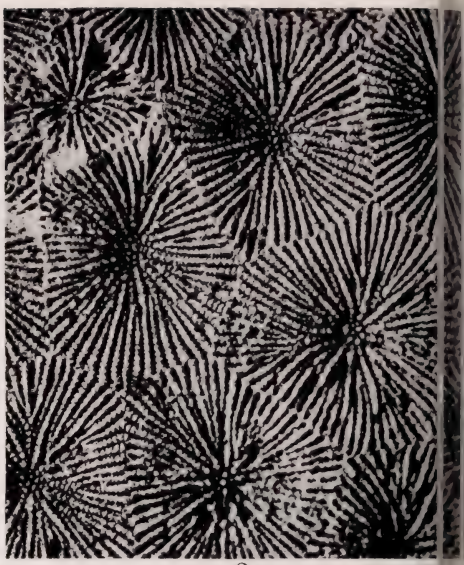
2a X 4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

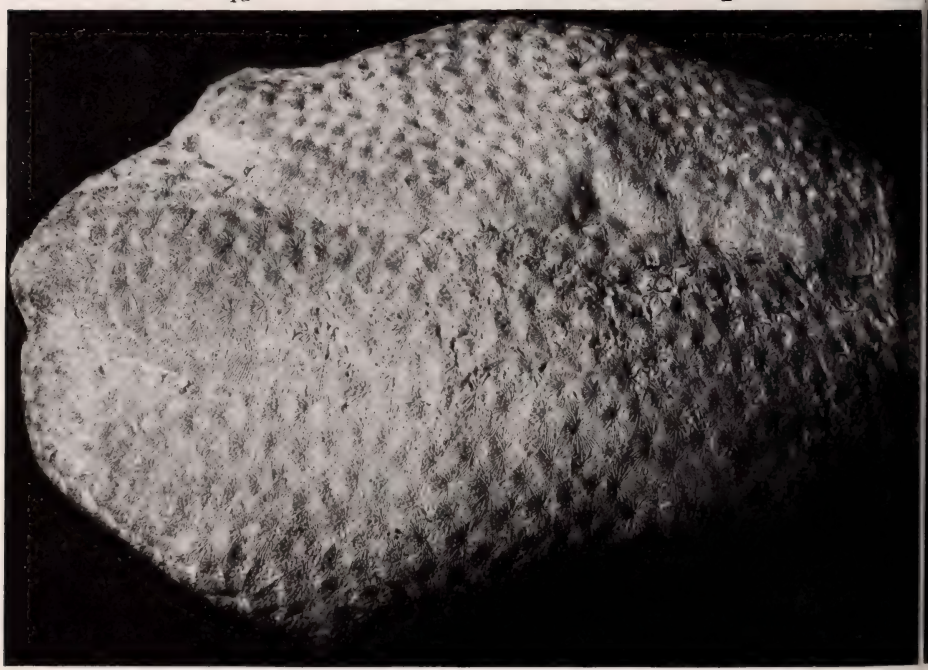
FOR EXPLANATION OF PLATE SEE PAGE 517.



1a × 4



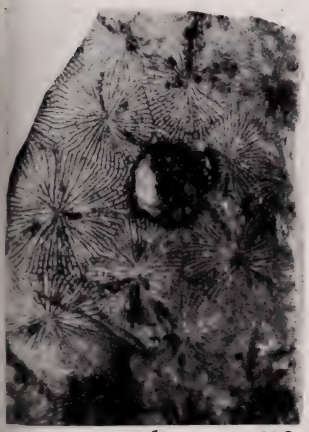
2 ×



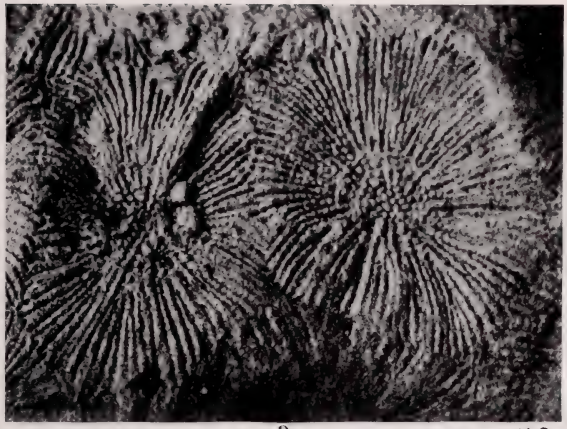
1

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

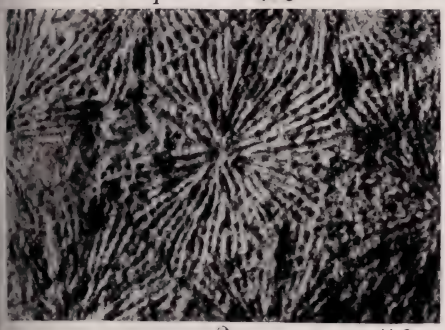
FOR EXPLANATION OF PLATE SEE PAGE 517.



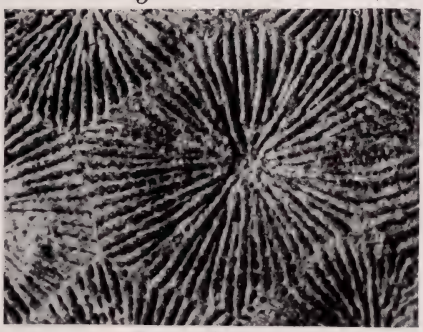
1 × 3



3 × 6



2a × 6



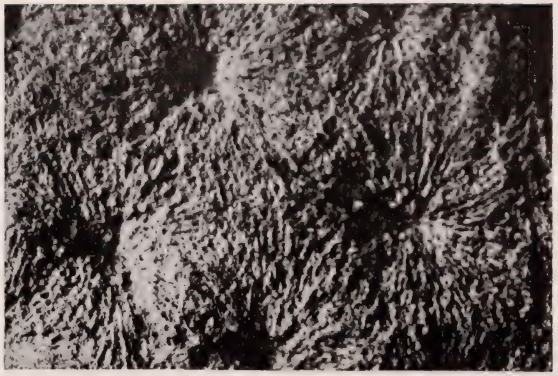
4 × 6

2

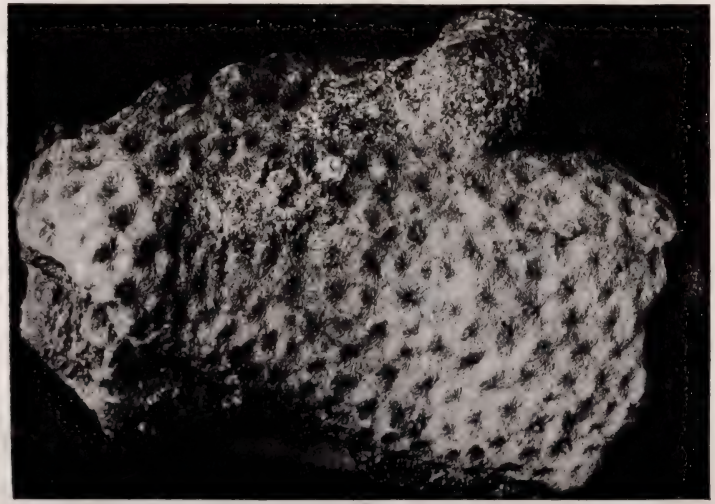
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 517.

1



1a X 6



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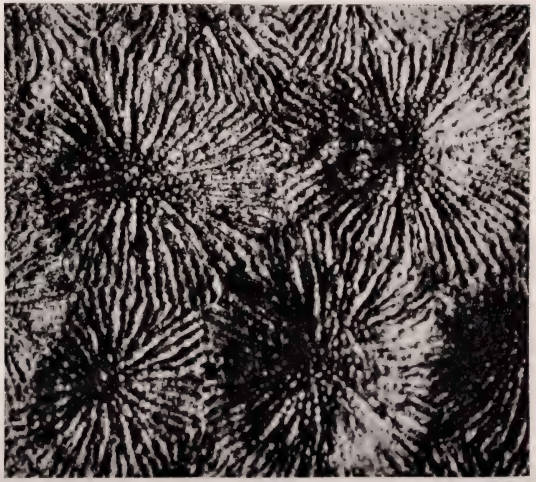
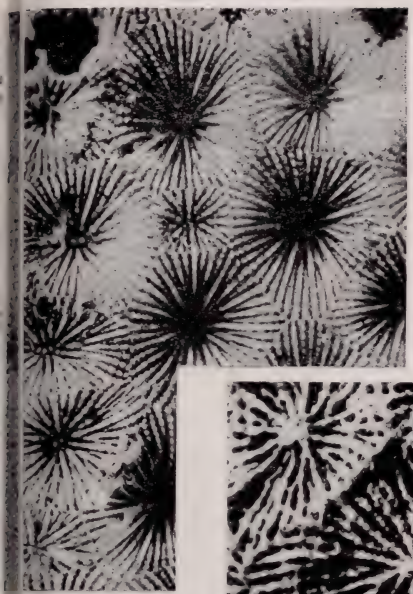


2a X 6



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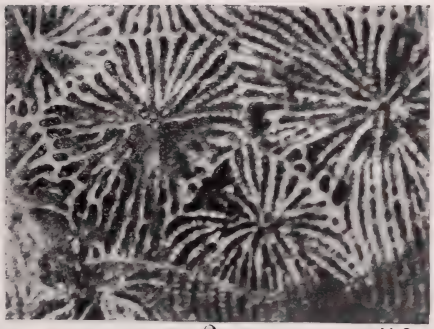
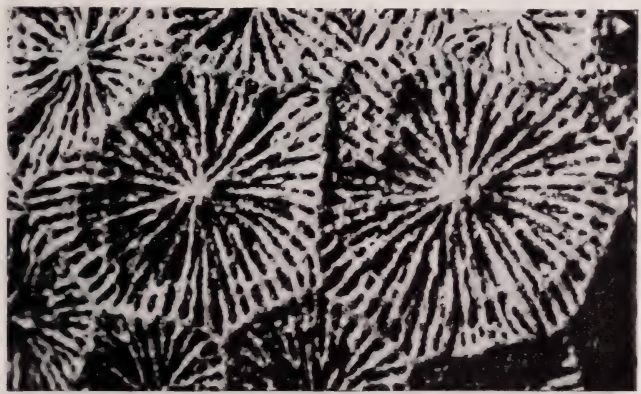
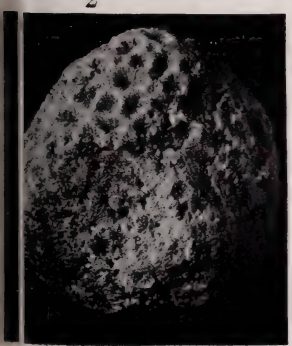


2a X 6



2b X 6

2



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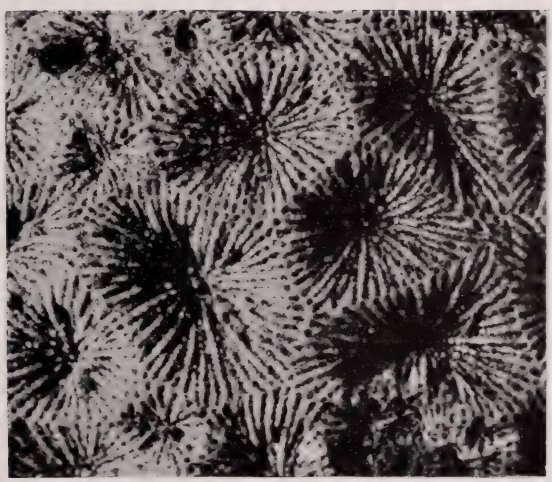
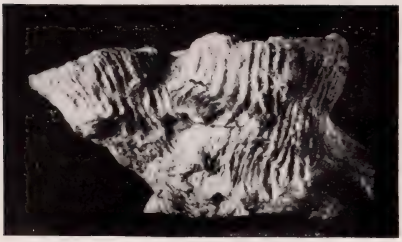


3a X 6

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.



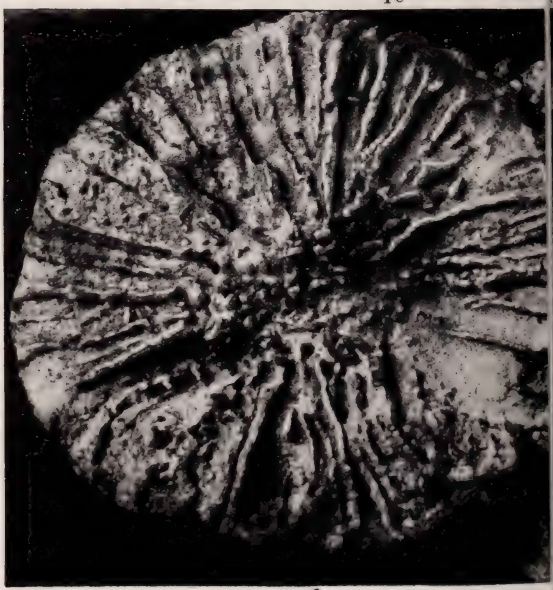
1

1b

1a

1c

1d X4

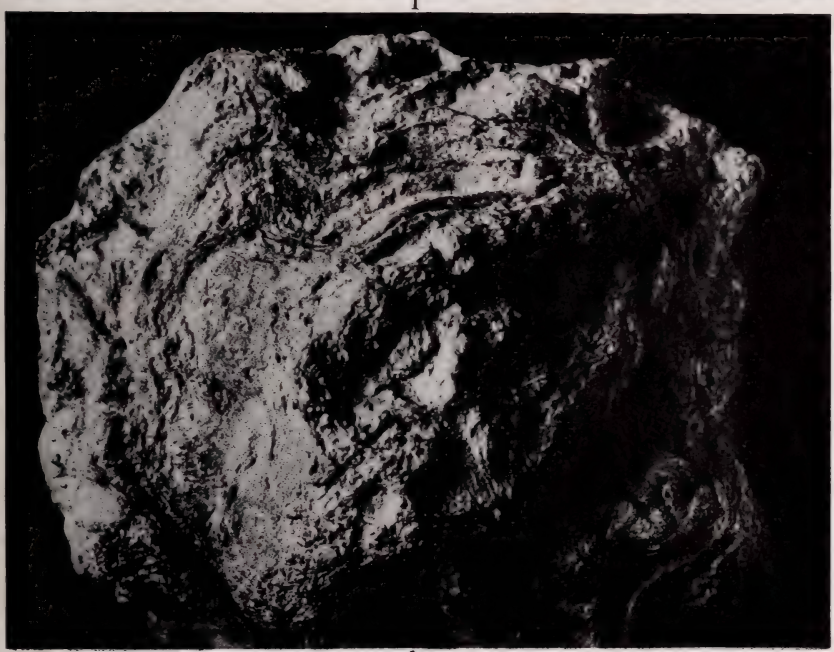


1e

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.

1



1a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.

1

1a

1b x 2

1c x 2

1d x 2

2

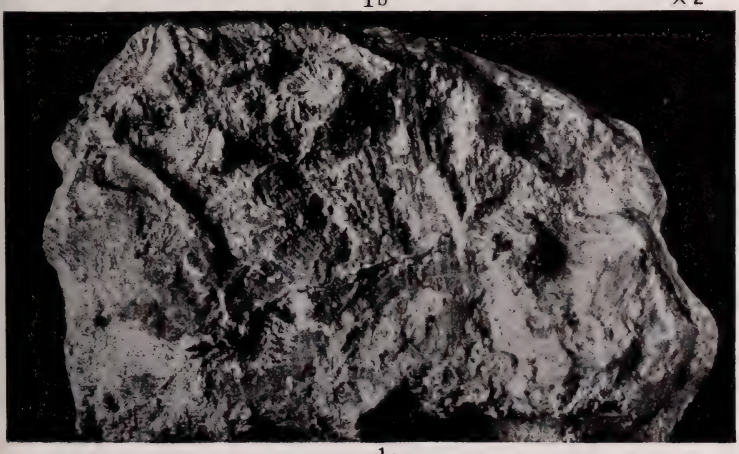
2a

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.

1

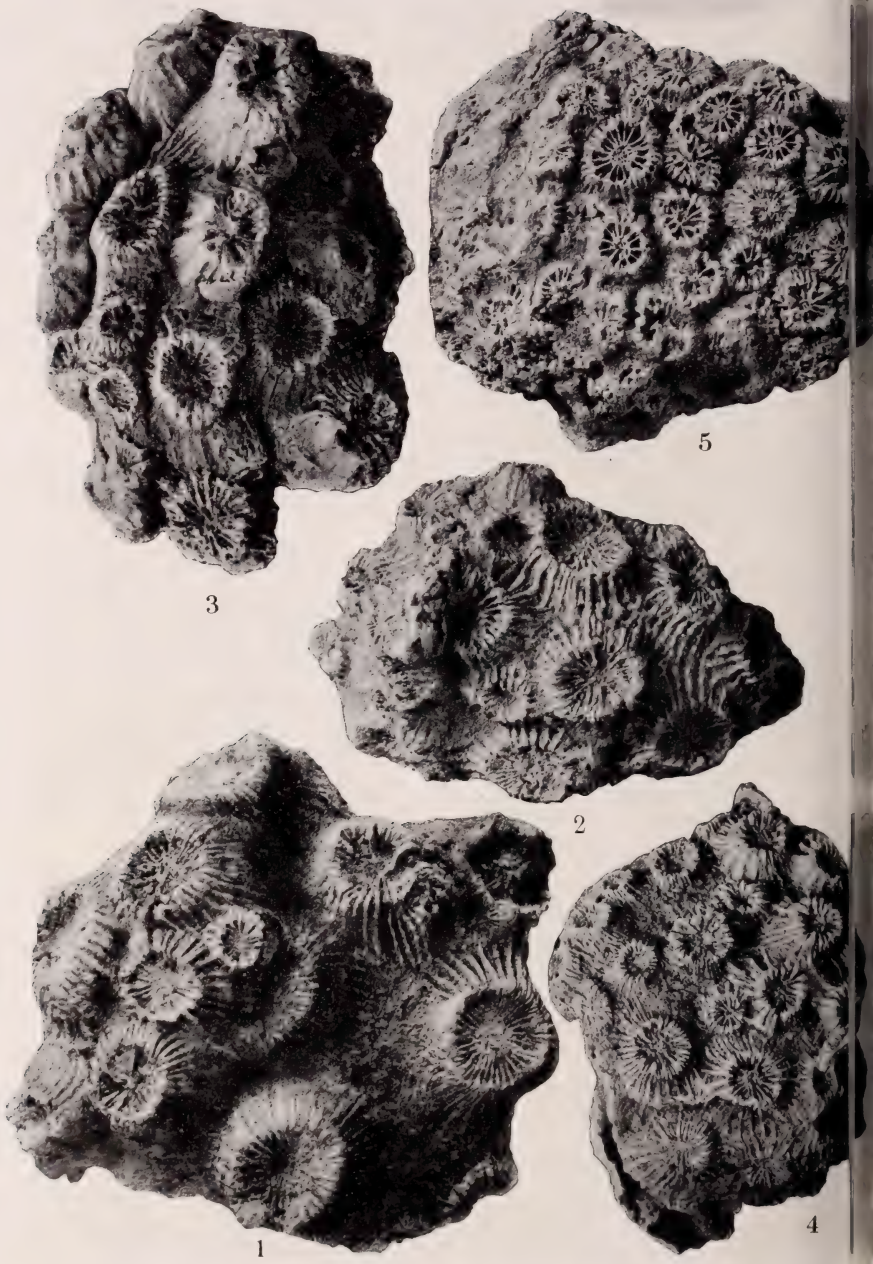
1b X 2



1a

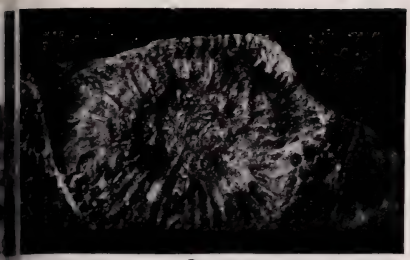
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 518.



FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 519.



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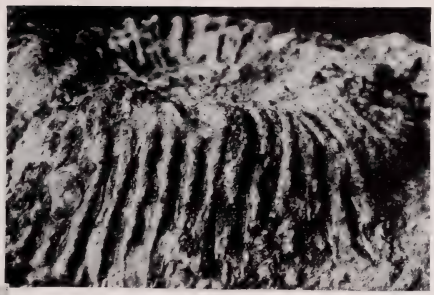
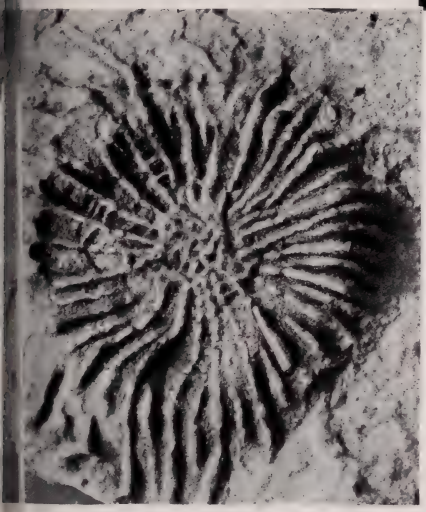
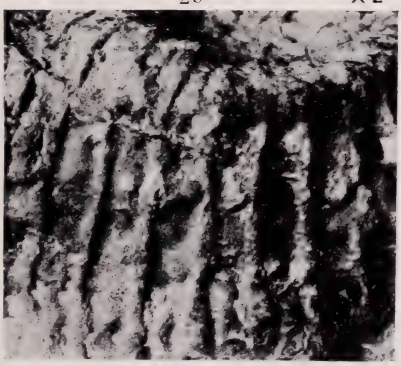


2b X 2



1b X 4



1a X 4

2a

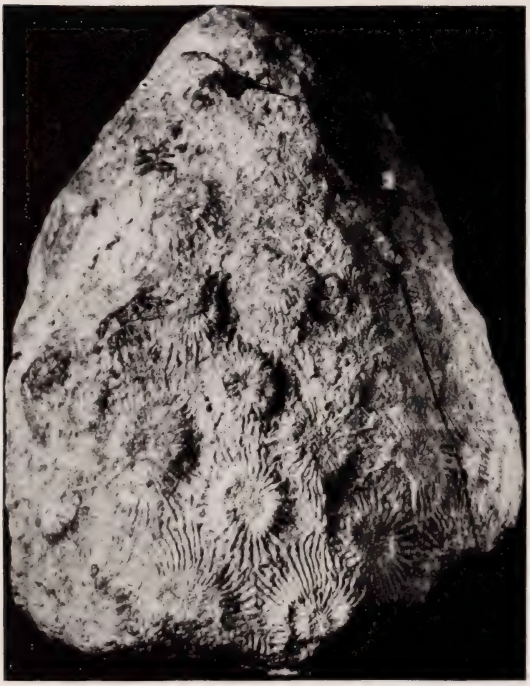
1

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 519.

1a X 2

1b X



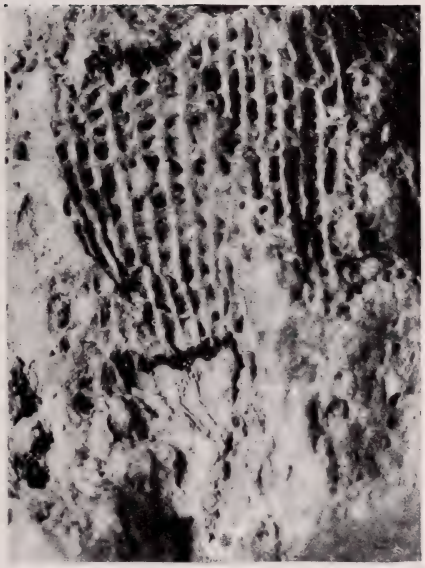
1

2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 519.

1 X 4



1a X 4

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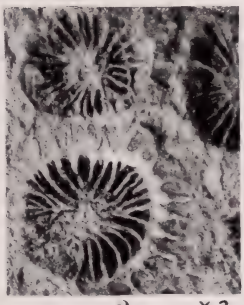
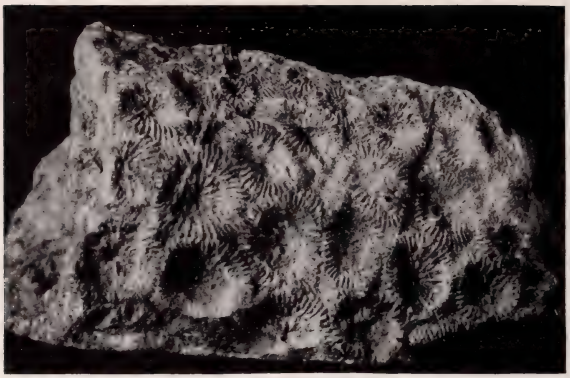


2a X 2

3

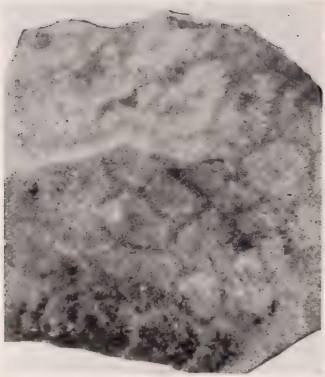
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 519.



1

1b X 4



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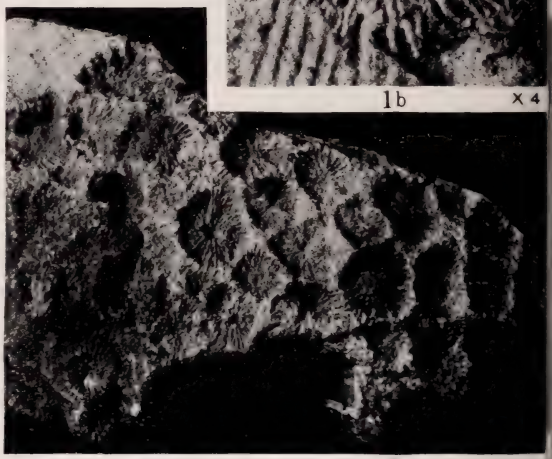

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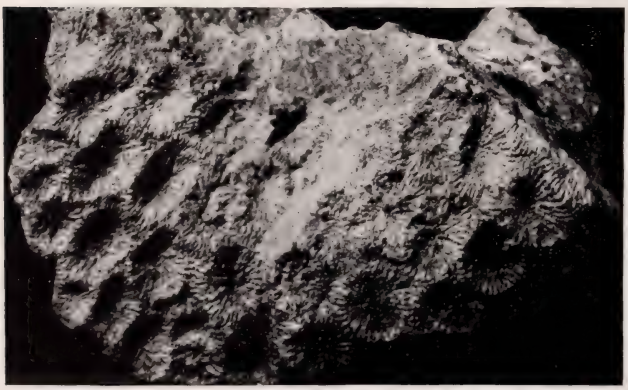
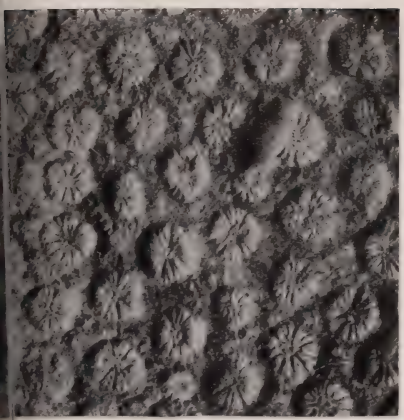


2

1a X 2

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGES 519 AND 520.



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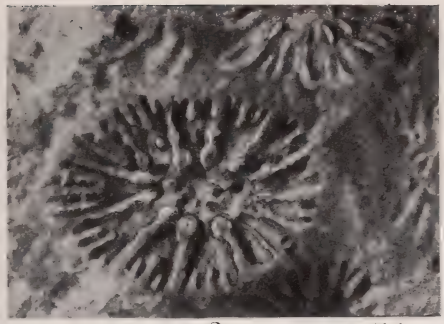
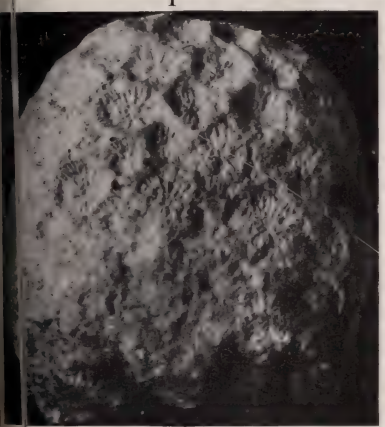
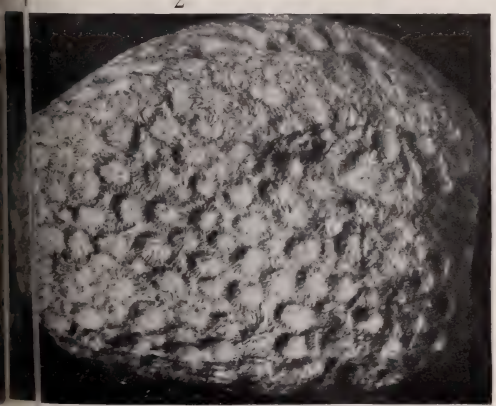


2a X 4



2

2b X 4



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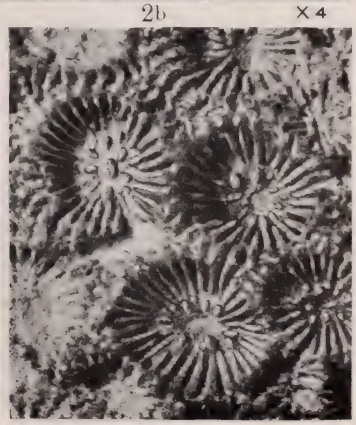
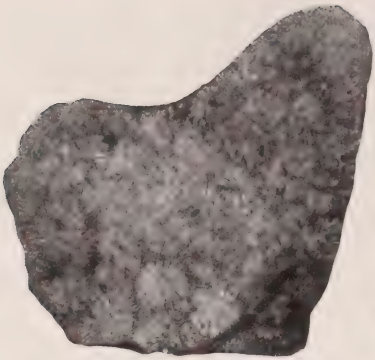


3a X 4

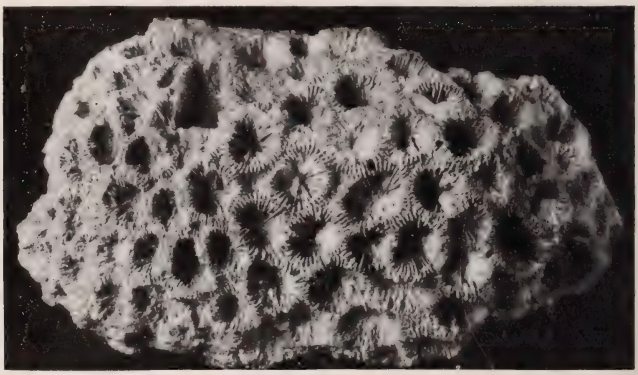
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 520.



1

2



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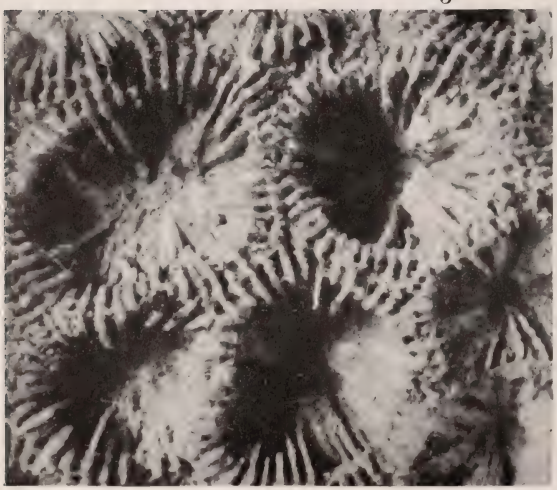
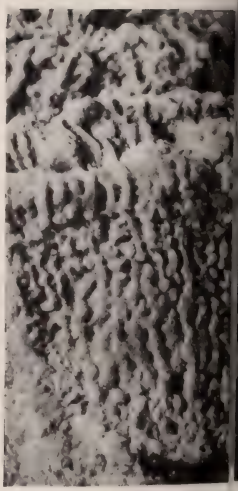


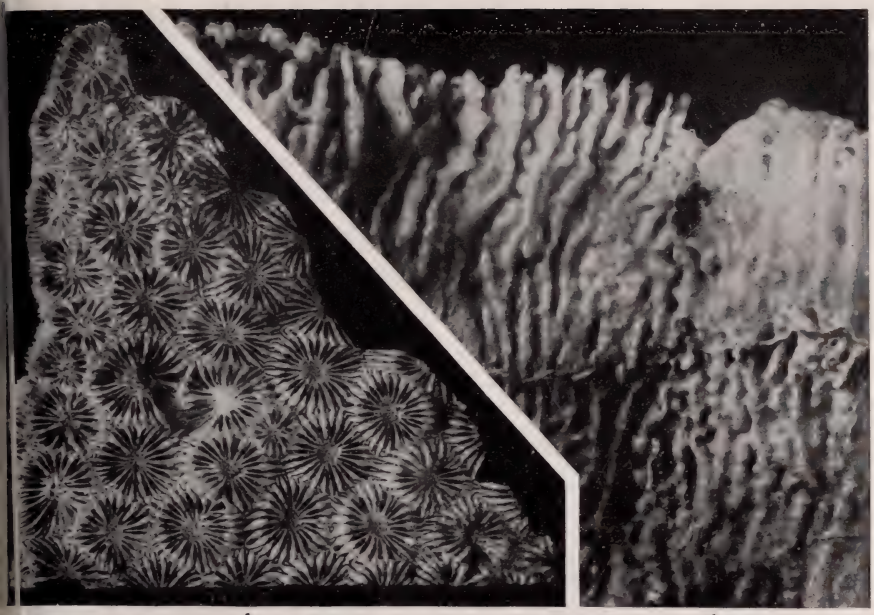
3a X 4



3b

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 520.



1 1a X 4

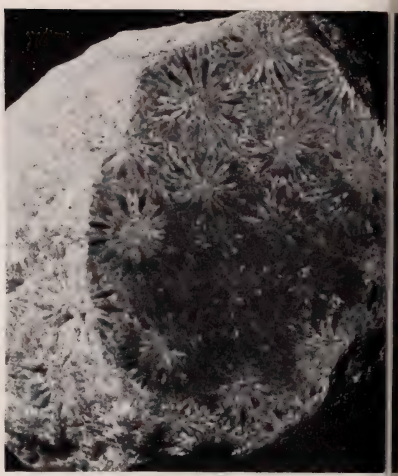
1b X 4

1c X 4

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 520.

1



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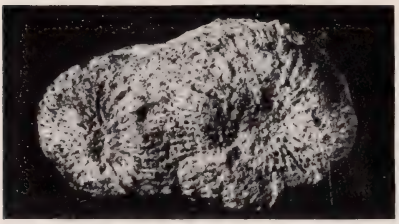
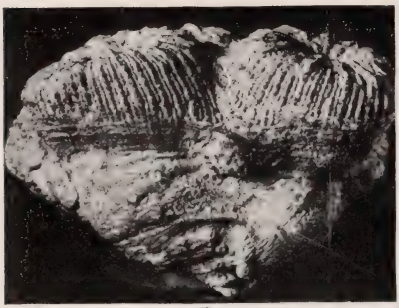


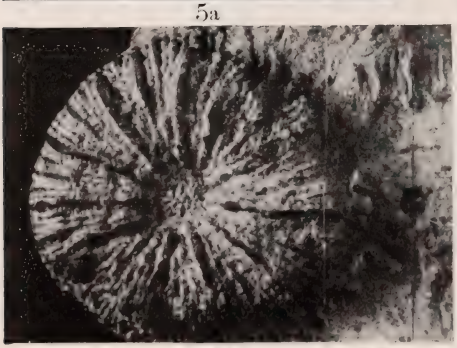
4a

3

4



5a



5b X 2

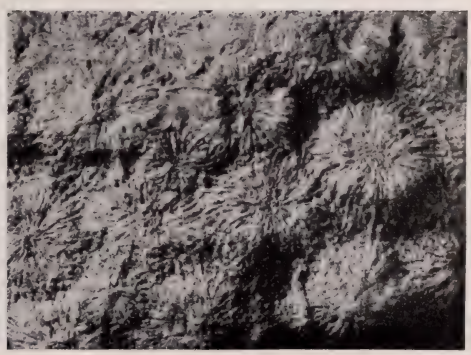
5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 520

1

1a X 2



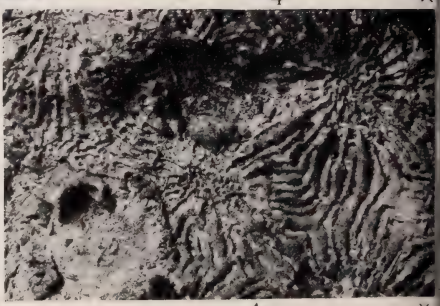
1b

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

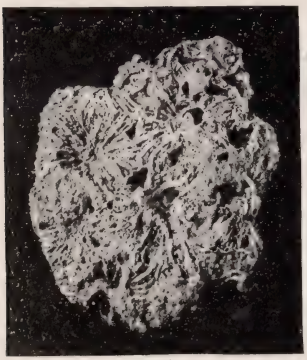
FOR EXPLANATION OF PLATE SEE PAGE 521.

3 X 2

4 X



4a X



5

2

1

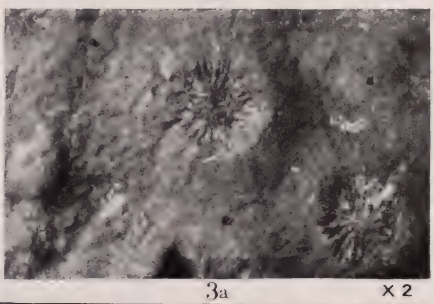
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 521.

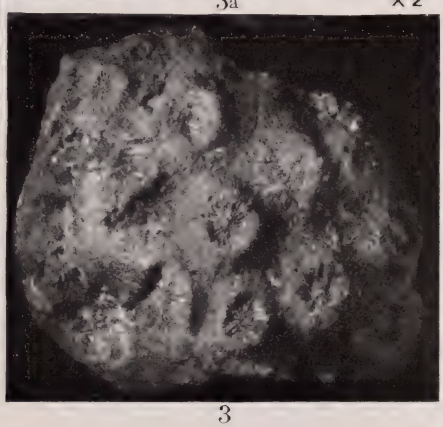
2

2a X 2

1



3a X 2



3

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 521.

1b × 3

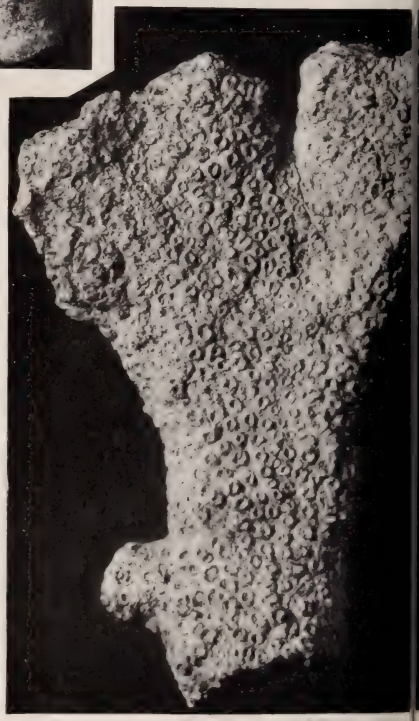
1

1a

2a × 3

2

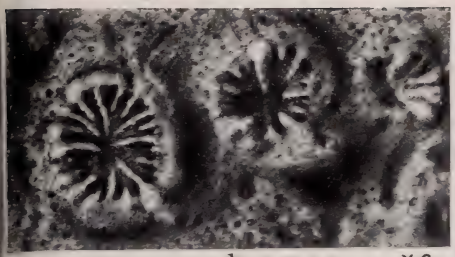
3a × 3



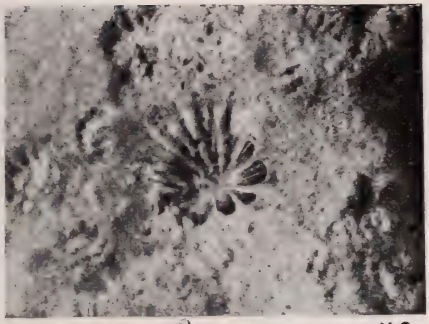
3

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

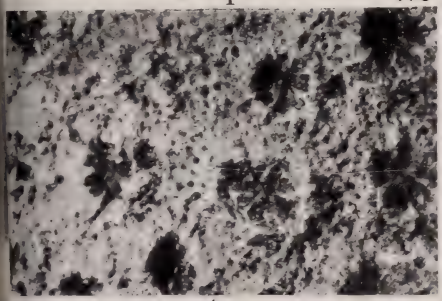
FOR EXPLANATION OF PLATE SEE PAGE 521.



1 X 6

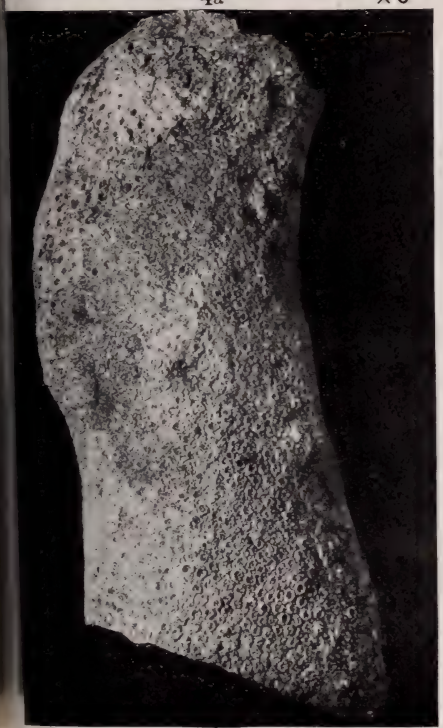


2a X 6

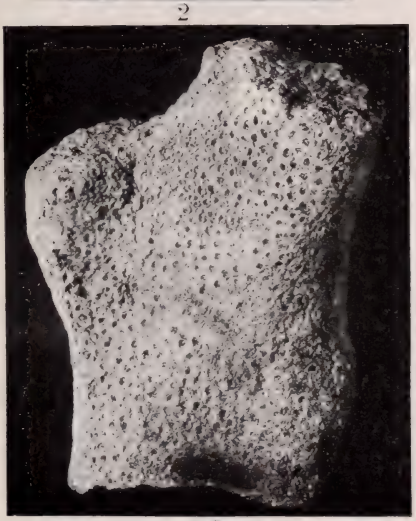


4a X 6

2



3 X ½



4 X ½

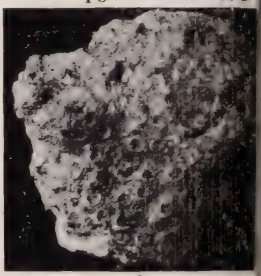
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 521.

1

3a X 3

1b X 8



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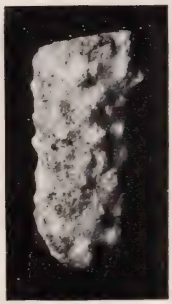

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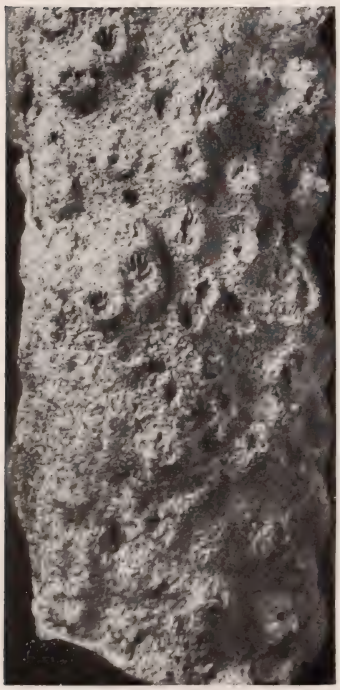

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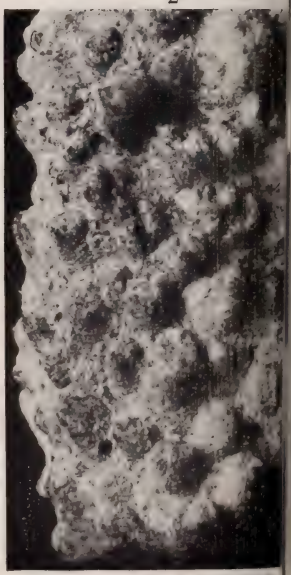
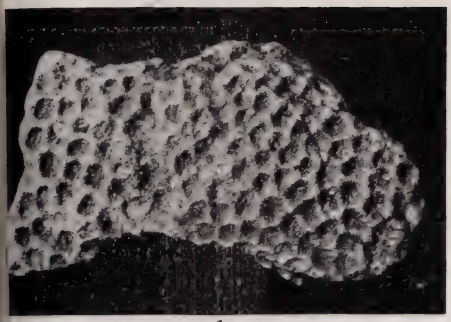


4a X 3

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 522.



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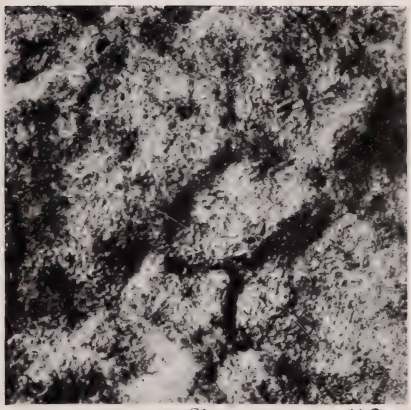

2b X 3

1a X 6

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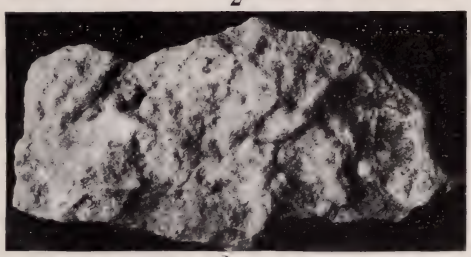

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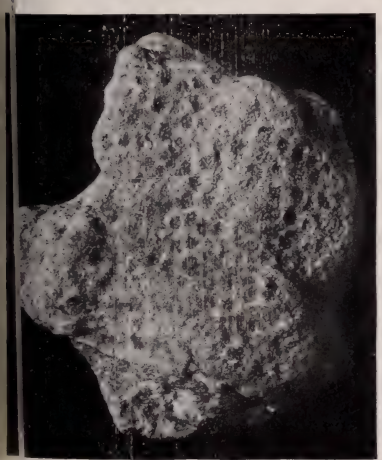

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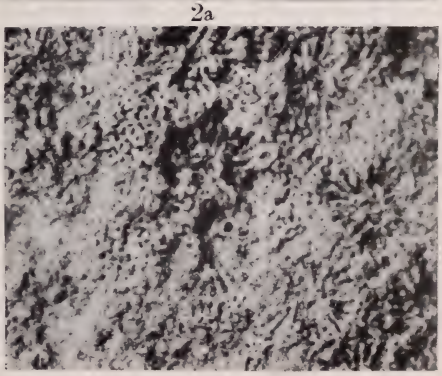


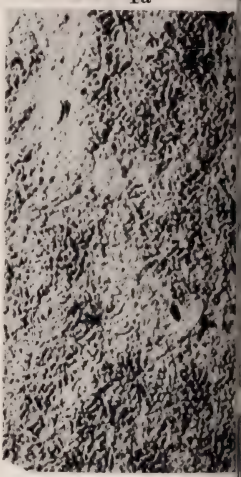
3a X 6

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 522

1

1a X 3



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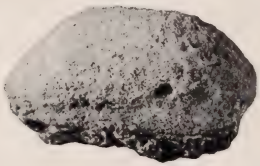

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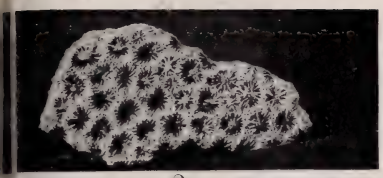
FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 522.



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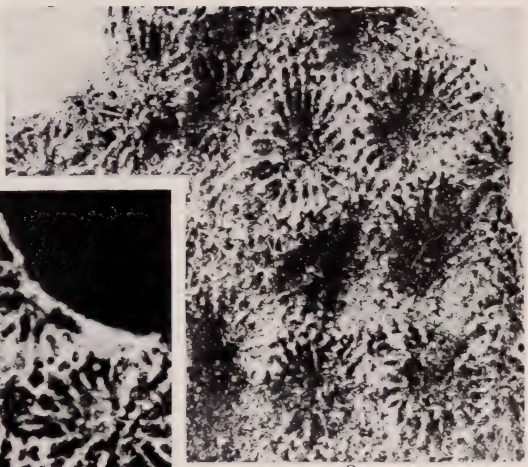

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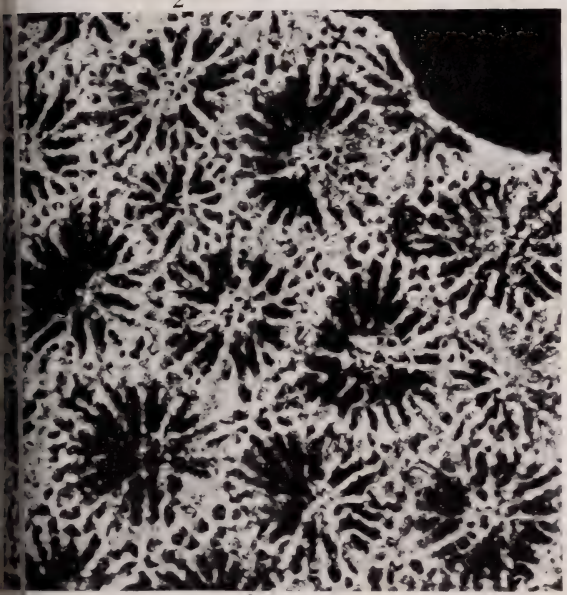

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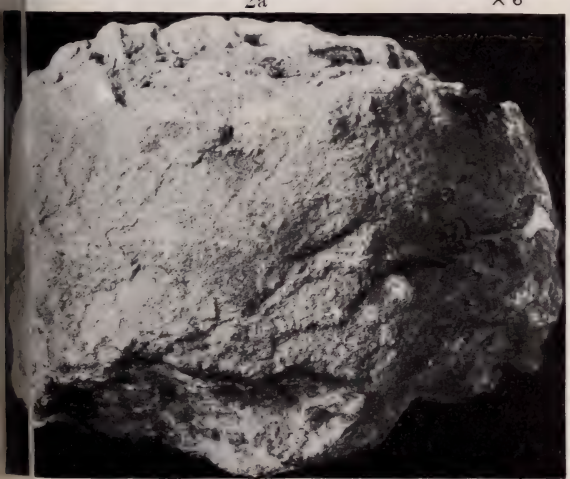
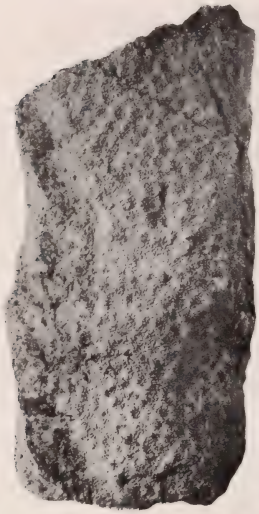


1 × ½

1a × 6

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 522.



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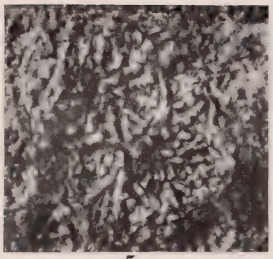

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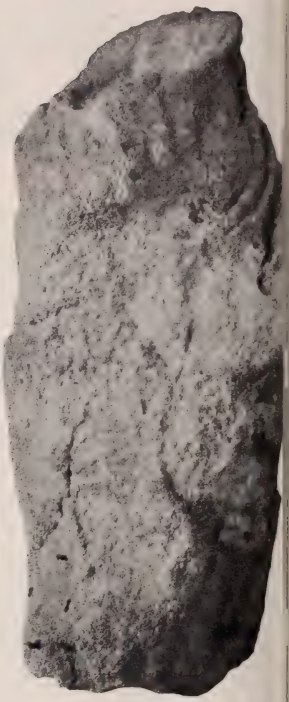
6a X 6



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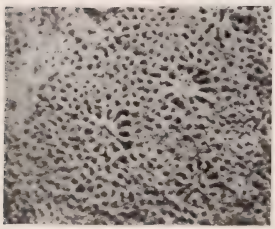

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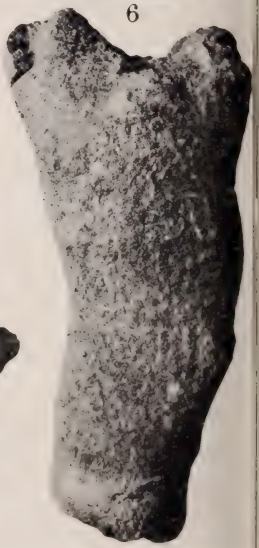

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FOR EXPLANATION OF PLATE SEE PAGES 522 AND 523.

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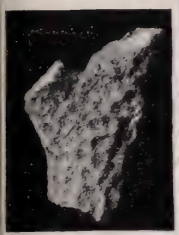
3 X 6



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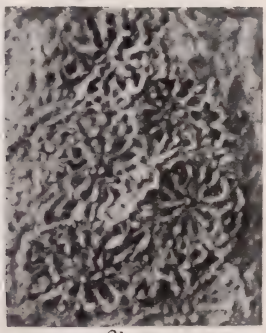

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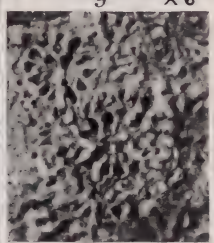

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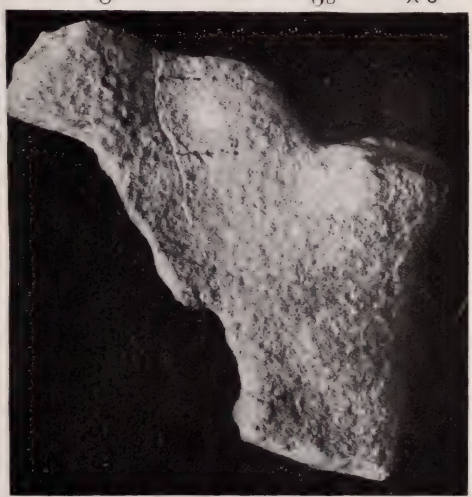

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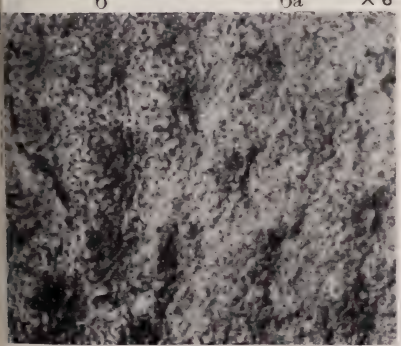


5 X 6

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES

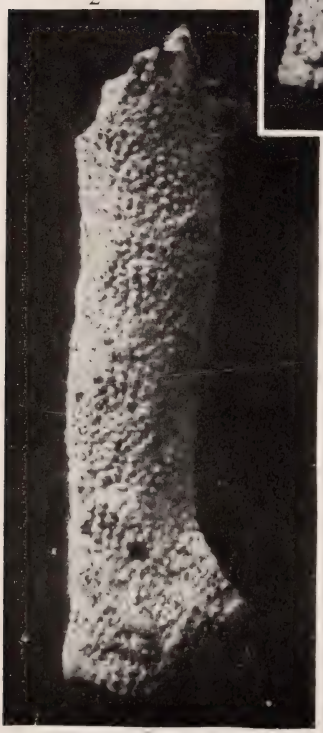
FOR EXPLANATION OF PLATE SEE PAGE 523.

1

2

3 X 5

4 X 5

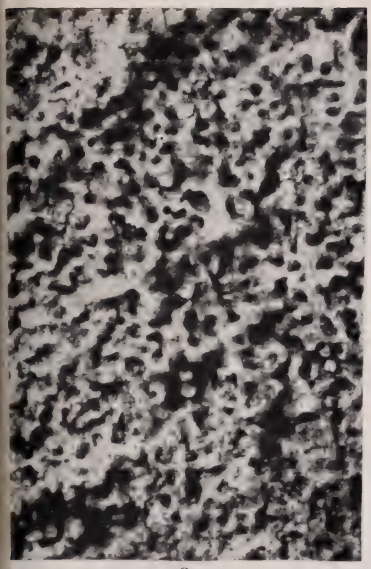


2a X 5

1a X 5

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 523.



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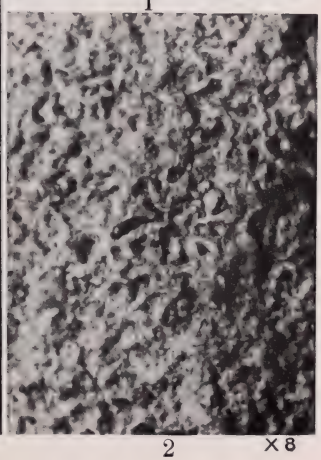

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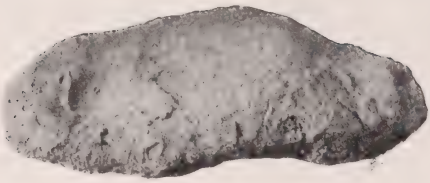
FOR EXPLANATION OF PLATE SEE PAGE 523.



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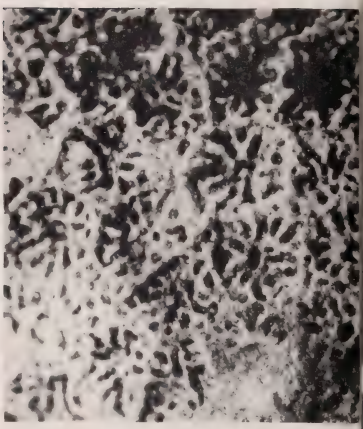

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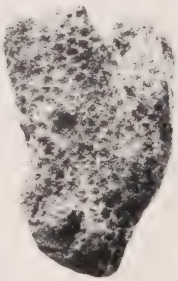

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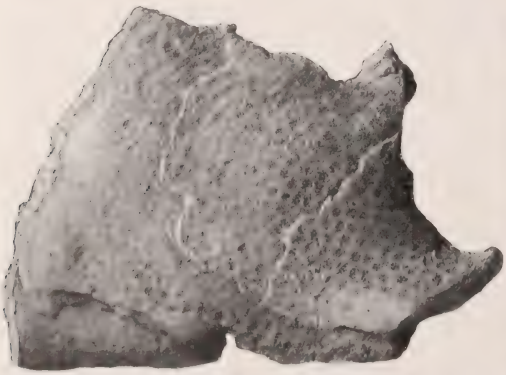
1a



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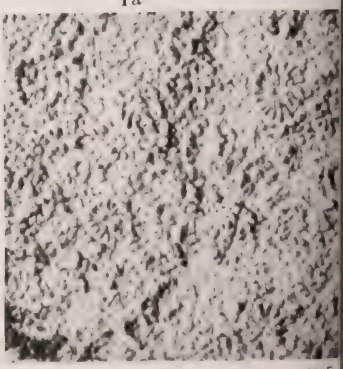

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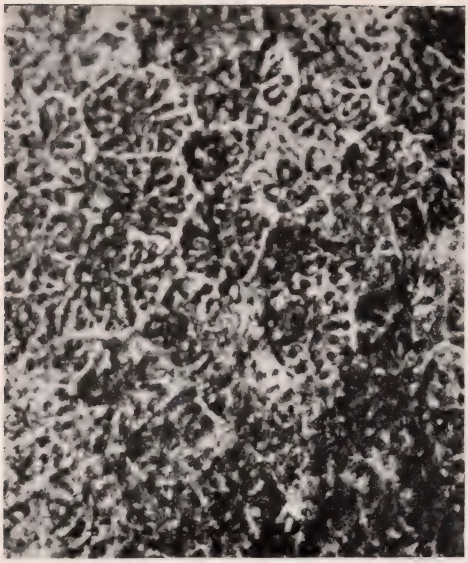
FOR EXPLANATION OF PLATE SEE PAGE 523.

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 524.



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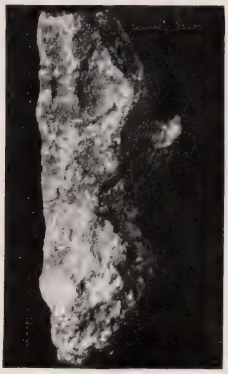

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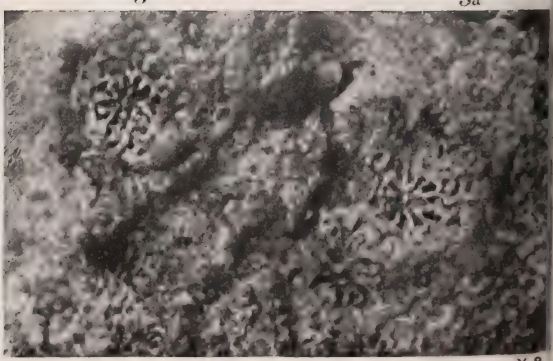
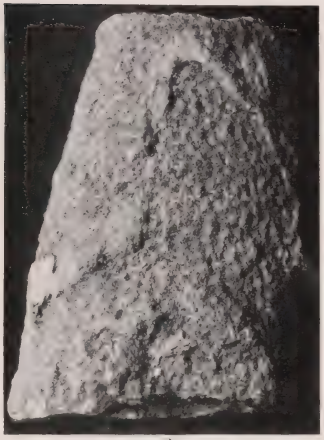


4 X 8

FOSSIL CORALS FROM CENTRAL AMERICA AND WEST INDIES.

FOR EXPLANATION OF PLATE SEE PAGE 524.

1



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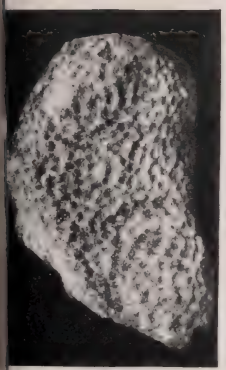

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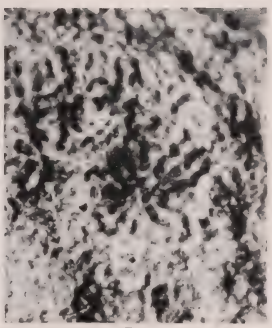

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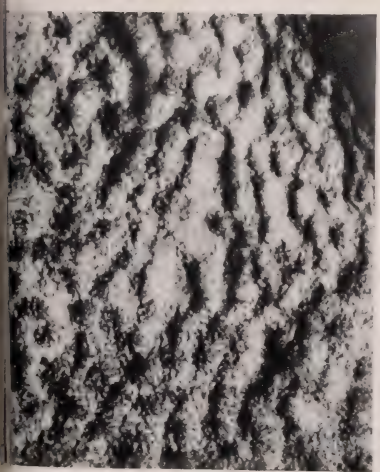

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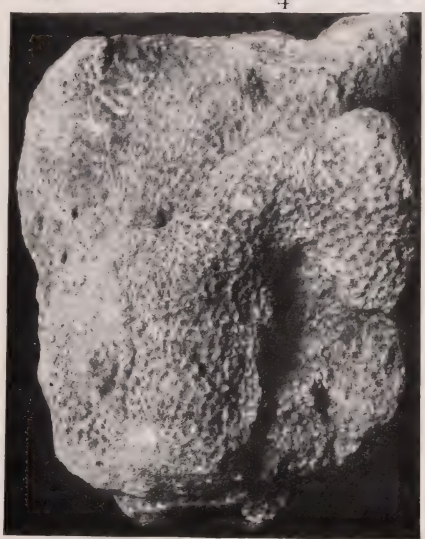

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UNITED STATES NATIONAL MUSEUM
Bulletin 103

CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

THE SEDIMENTARY FORMATIONS OF THE PANAMA CANAL ZONE, WITH SPECIAL REFERENCE TO THE STRATIGRAPHIC RELATIONS OF THE FOSSILIFEROUS BEDS

By DONALD FRANCIS MacDONALD
Formerly Geologist of the Canal Commission

Extract from Bulletin 103, pages 525–545, with Plates 153–154

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THE SEDIMENTARY FORMATIONS OF THE PANAMA CANAL ZONE, WITH SPECIAL REFERENCE TO THE STRATIGRAPHIC RELATIONS OF THE FOSSILIFEROUS BEDS.

By Donald Francis MacDonald,
Formerly Geologist of the Canal Commission.

INTRODUCTION.

The following summary statement regarding the stratigraphic geology of the Canal Zone is intended to make clear the stratigraphic relations of the deposits from which the fossils described in the accompanying memoirs were obtained. The descriptions of the successive formations are taken from my paper entitled "Some engineering problems of the Panama Canal in their relation to geology and topography,"[1] except that Dr. T. W. Vaughan has changed the age classification of the formations as published in the bulletin cited by referring the Bohio conglomerate to the Oligocene and by placing the Gatun and Panama formations in the Miocene. The small scale map (pl. 153), scale about 5 miles to 1 inch, is a republication of the map contained in the same paper, of which it is plate 4. It should be noted here that the Culebra formation outcrops at locality station 6024, below the Emperador limestone, on Rio Agua Salud; locality station 6025, Bohio Ridge; locality station 6026, about 2 miles southwest of Monte Lirio; and locality station 6027, in the old site of Bohio before the relocation of the Panama Railroad. The position of each of these stations is shown on plate 154. The electrotypes for figures 26 and 27 were loaned by the United States Bureau of Mines.

The detailed descriptions of the local stations, which follow the accounts of the geologic formations, except that of Bald Hill, near Miraflores Locks, were made more or less jointly by Doctor Vaughan and myself. The study of these exposures by both of us supplies to Doctor Vaughan the basis for the accurate placing of the fossils obtained in their stratigraphic relations. He prepared the key map of localities here reproduced as plate 154.

[1] U. S. Bureau of Mines Bull. 86, pp. 83, 29 pls., 9 figs., 1915. Particularly pp. 17–26.

The localities for the fossils are indicated as the station number in the United States National Museum record book for Cenozoi invertebrate fossils. In order to obviate confusion, as the Cana Commission also had station numbers, the United States Nationa Museum numbers are printed in heavy-faced types in the descrip tions of the exposures, while the Canal Commission numbers ar printed in italics.

SEDIMENTARY FORMATIONS.

Eocene (?).

BAS OBISPO FORMATION.

The Bas Obispo formation is the oldest Isthmian formation, so fa as is known, and although referred doubtfully to the Eocene it ma be of pre-Tertiary age. It was formed of rock fragments and ash blown from old volcanic vents. The débris settled over the sur rounding region and was subsequently cemented into fairly hard rock by the slow-acting processes of rock cementation. Locally i shows some rough bedding and some rounded water-worn fragments In composition it belongs to the andesitic tuff group of rocks although locally it might be classed as andesitic breccia. It outcrops extensively at Bas Obispo and near old Panama, and small outcrops rise above the alluvium near Miraflores and Diablo Ridge.

LAS CASCADAS AGGLOMERATE.

The Las Cascadas agglomerate also had its origin in fragmenta rock material blown from volcanic vents and later washed down into different beds and masses. It rests unconformably on the Bas Obispo formation, is much less consolidated and cemented than the latter, and is of much more recent origin. It is a greenish to gray, basic agglom erate, which contains large and small subangular fragments in a fine-grained groundmass of volcanic clay and tuff. The whole is arranged in massive to roughly bedded deposits, often unconformable with each other. Interbedded with these deposits are andesitic flow-breccias, some fine-grained grayish and some coarse-grained dark andesitic flows, and a few easily crumbled lava-mud flows which show columnar jointing where exposed in the canal. The whole is cut by large and small basalt dikes. The formation outcrops extensively along the canal between Empire and Las Cascadas.

Oligocene.

BOHIO CONGLOMERATE.

The Bohio conglomerate consists of beds containing water-worn cobblestones and pebbles. These beds are separated from each other by layers of sandstone and clay rock. The lower part of the formation contains more cobbles and pebbles than the upper part and seems

to be largely a product of running water. It is generally fairly well bedded, though locally massive, and contains hard boulders, up to a few feet in diameter, of andesitic, dioritic, and other igneous rocks.

The upper part of this formation is of the same general composition as the lower part, but contains some beds of dark-gray clay marl which contain fossil Foraminifera. The cobbles, boulders, and gravel are from cherts, andesites, and diorites, and were derived from the older intrusive masses of igneous rock now found at intervals along the central part of the Isthmus.

The formation must be at least 1,000 feet thick, and it outcrops extensively in the vicinity of Bohio and near Caimito Junction. Though not outcropping in the Gaillard Cut, it was encountered in many of the cuts near Bohio on the new line of the Panama Railroad.

CULEBRA FORMATION.

The Culebra formation contains an upper and a lower member.

The lower member consists of dark, well-laminated beds of soft shales, marls, and carbonaceous clays, with some pebbly, sandy, and tufaceous layers. There are a few thin beds of lignitic shale, but the whole upper part of the formation contains considerable organic matter. It outcrops in Gaillard Cut near Culebra and near Pedro Miguel.

The upper member consists of calcareous beds and lenses ranging in character from sandy limestone to calcareous sandstone, 3 to 10 feet thick, separated by partings of dark carbonaceous clays and fine-bedded tuffs.

Locally this formation gives off a little natural gas and in some small areas it shows slightly bituminous shales.

CUCURACHA FORMATION.

The Cucuracha formation is here described in considerable detail, because in it not only the Cucuracha slide but also the big Culebra slides developed. It is so named because of being the site of the Cucuracha slide and because it is typically exposed near Cucuracha village.

The formation consists of a dark green, massive and locally bedded, slightly indurated, volcanic clay rock of andesitic composition. It is a land-deposited formation, overlying the marine Culebra formation, from which it is separated by 10 to 20 feet of slightly indurated gravel. It is the upper part of what Hill [1] and Howe [2] called the Culebra formation.

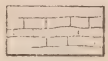
---

[1] Hill, R. T., Geological history of the Isthmus of Panama and portions of Costa Rica, Museum Comparative Zoölogy Harvard College Bull., vol. 28, 1898.

[2] Howe, Ernest, Canal Commission Ann. Rept. 1907, Appendix E, pp. 108–138; Isthmian geology of the Panama Canal, Econ. Geol., vol. 2, 1907, pp. 639–658; Geology of the Isthmus of Panama, Amer. Journ. Sci., ser. 4, vol. 26, 1908, pp. 212–237.

SUCCESSION OF BED ROCKS.

Pleistocene. 11. c. River alluvium. b. Muds and silts. a. Gravel.

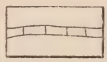


Pliocene. 10. Toro limestone. Shell marl and limestone.

Miocene. 8. Panama formation. Light colored tuff beds, argillite, etc.

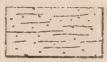
9. Gatun formation. c. Clay beds. b. Fine sandstone. a. Argillite.

Oligocene. 7. Caimito formation. c. Sandstone. b. Limy conglomerate. a. Sandstone.

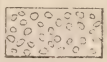


6. Emperador limestone. Marine limestone, many corals.

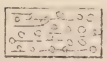
5. Cucuracha formation. Land formed clay rocks, lava flow, etc.



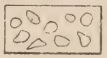
4. Culebra formation. Marine carbonaceous shale, clay, tuffs, limy sandstone.



3. Bohio conglomerate. Coarse and fine conglomerate and sandstone beds.



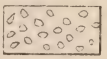
Eocene? 2. Las Cascadas agglomerate. Volcanic débris, mud-lava, some flows and dikes of andesite.



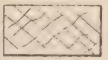
1. Bas Obispo formation. Volcanic breccia.

SUCCESSION OF IGNEOUS ROCKS.

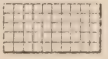
Miocene? (Mostly). 6. Basalt.



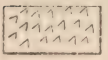
5. Meta-breccia.



4. Rhyolite.



3. Andesite.



(?) 2. Diorite.

1. Grandiorite.

FIG. 26.—ROCK SUCCESSION IN THE CANAL ZONE. (From U. S. Bureau of Mines Bull. 86.)

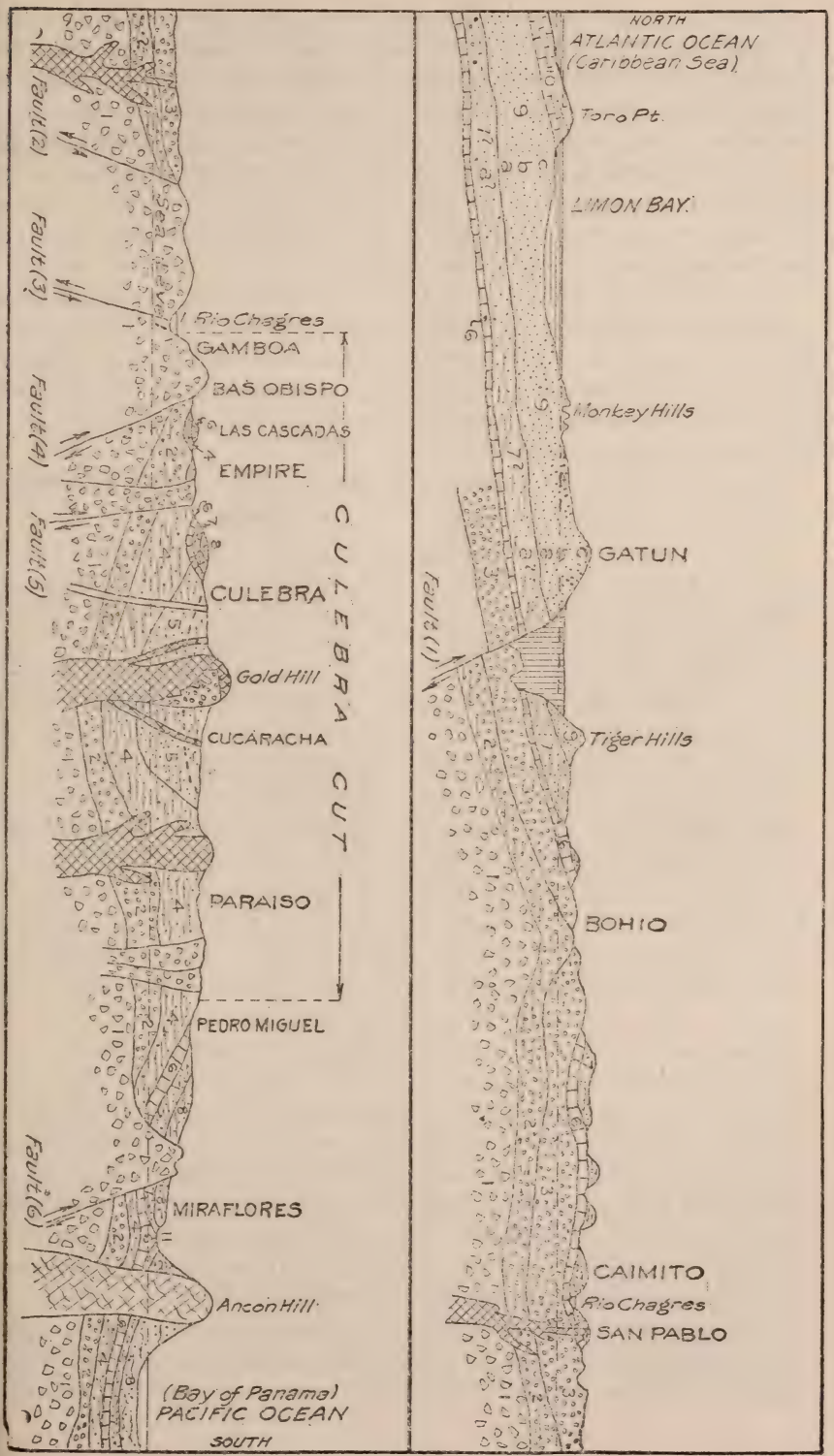


FIG. 27.—GENERALIZED GEOLOGIC SECTION ACROSS THE ISTHMUS

Locally it contains red beds and lenses, but these are of the same general character as the green clay rock in which they are interbedded, except that they contain slightly more iron and alumina and a little less silica. In certain beds there is a network of small irregular joints, contiguous to which the greenish clay rock has turned red; such a change seems to be due to the oxidation of the greenish ferrous iron to the red ferric condition by surface waters. In some of these red beds, however, there has been some local concentration of iron and alumina products.

In addition to the red beds there are a few local beds and lenses of gravel and of sandy, dark-gray, tufaceous material. This gravel, like the gravel at the base of the formation, is fairly fine, loosely cemented, and consists of the rounded fragments of indurated shales, cherts, and concretions from the lower part of this formation and from some of the older rocks.

There are also four distinct beds of lignitic shale, 1 to 5 feet thick. They are the fossilized remains of former swamps.

The formation is cut by some large and some small basaltic dikes, but these have caused scarcely any metamorphism. Faulting has considerably broken the beds and, owing to their soft and brittle character, relatively small faults, where the movement seems to have been less than 75 feet, have resulted in shear zones up to several feet wide. These rocks weather readily, and are covered by 10 to 25 feet of red soil. They are easily eroded, so that the outcrops of this formation have mostly been worn into flats or valleys.

Extending for more than a mile over what must have been an old land surface, and now forming an interbedded unit of this formation, is a light to dark grayish, or, on fresh fracture, greenish, lava-breccia flow of andesitic composition. Hand specimens of it show a few little shiny faces of feldspar crystals up to 2 mm. in length, set in a groundmass that resembles indurated clay. The brecciated fragments are small, somewhat altered, and seem to have been picked up from the formation over which the flow moved. Under the microscope the rock is seen to consist of euhedral phenocrysts of andesine ranging in size up to 1 by 2 mm. and some crystals of potash feldspar set in a cloudy claylike groundmass, dark scaly areas resulting from the decomposition of some mineral, considerable chlorite, some calcite, and a little secondary quartz. The outlines of the brecciated fragments were recognized, but their original composition was obscured by alteration. This altered andesite flow is somewhat jointed and weak, so that it adds but little strength to the slopes and is practically no protection against slides.

The prevailing grayish-green color of the formation is due to the fairly high percentage of very finely divided chloritic material that it contains. These greasy mineral particles are a marked source of

weakness and mobility and are one of the factors that have caused maximum sliding in this formation. In contrast with the clays of the Culebra formation, these rocks are massive, largely of terrestrial origin, contain little organic matter outside of the few lignitic shale beds mentioned, have a greenish color from a high chlorite content, and are much more given to sliding than the other rocks.

EMPERADOR LIMESTONE.

The Emperador is a light-colored, fairly pure limestone. It lies unconformably on several of the older beds. Its outcrops are comparatively small and weather locally into a pitted and platy condition. Near Las Cascadas a section cut by the canal shows the limstone, about 25 feet thick, overlying the upper part of the Culebra formation. It outcrops northwest of Empire, south of Las Cascadas, on the new line of the Panama Railroad near San Pablo, near Frijoles, in the swamp southeast of Diablo Ridge, and extensively near Alhajuela.

CAIMITO FORMATION.

The Caimito formation, which overlies the Emperador limestone, consists of three members, as follows: (*a*) A basal light-gray, soft, argillaceous, or clay-like, sandstone, which grades upward into a yellowish argillitic sandstone that is bluish gray on fresh fracture; (*b*) a peculiarly calcareous conglomerate with some fragments of much decayed basic rock, which locally give a bright-green stain to small patches of the formation; (*c*) a light-colored to yellowish argillaceous sandstone fairly well bedded. The upper argillitic sandstone is the rock that outcrops in the Chagres River at Barbacoas, near San Pablo. Beds *a*, *b*, and *c* may be seen in the section at Bald Hill, north of Miraflores. Bed *b* outcrops extensively at San Pablo and near the site of the proposed wireless telegraph station opposite San Pablo. The formation does not outcrop at all in Gaillard Cut.

MIOCENE.

GATUN FORMATION.

The Gatun formation consists of three members, as follows: (*a*) About 500 feet of marls and argillites, or clay rocks, and some beds of soft sandstone and conglomerate; this member is bluish gray but locally contains many brown specks, indicating fragments of organic material; it is rich in the fossil shells of ancient marine life; (*b*) mostly fine, soft sandstone, about 100 feet thick, containing a few fossils; (*c*) light to creamy gray indurated clay beds.

The formation is extensive and constitutes the foundation on which the Gatun Locks are built. Fortunately, its fineness of grain renders it relatively impervious to ground water. The upper part

of the formation weathers into red clay, and it covers the solid rock to a depth of 10 to 25 feet, except where it is cut through by streams.

PANAMA FORMATION.

The Panama formation is a light-colored well-bedded tuff somewhat acid in composition. Locally it contains some argillaceous beds. It outcrops extensively from Miraflores to Panama and in a few other places. The formation is at least 400 feet thick and overlies the Caimito formation. It seems to be relatively porous, fairly well bedded, somewhat jointed, and of a crumbly or friable nature.

PLIOCENE.

TORO LIMESTONE.

The Toro [1] limestone is sandy and fragmental, and locally is a coquina or shell marl. Its type locality is at Toro Point, but similar appearing limestone fringes the Caribbean coast, except where large valleys have caused it to be eroded or covered with alluvium. In places it forms low bluffs or headlands, expecially at Toro Point, west of the Gatun Dam, and at the mouth of Chagres River. It is the rock from which Fort San Lorenzo was built. Rock from this formation was used as a hearting for the Toro Point Breakwater.

CHAGRES SANDSTONE.[2]

The name Chagres sandstone is proposed for a massive, coarse-grained, rather soft sandstone, that locally shows stratification and considerable cross-bedding. Some of the beds contain a few poorly preserved bivalves and dark to brownish fragments of organic matter are not uncommon. This appears to be a land or beach deposit, and is probably as much as a thousand feet or even more thick. It is tilted oceanward at angles ranging from 5 to 20 degrees and lies on top of the Toro limestone on which it may or may not be conformable. It forms the hills overlooking the coast between Toro Point and the mouth of Chagres River.

PLEISTOCENE.

The Pleistocene formations consist of (*a*) swamp deposits, black soil, and silt, filling old channels to depths of 325 feet below the present sea level; (*b*) river gravels up to 10 feet above the present normal river levels; (*c*) old sea beaches 6 to 10 feet above the present beach level; and (*d*) bars, beaches, and the present river alluvium.

DESCRIPTION OF LOCAL SECTIONS ACROSS THE ISTHMUS OF PANAMA.

The black-faced numbers in the following descriptions are the station numbers in the United States National Museum register of Cenozoic invertebrate collections

[1] Called Caribbean limestone by the author in reports of Isthmian Canal Commission for 1912 and 1913. See p. 63 and p. 570 of report for 1913.

[2] The name and description of this formation were added to the proof of this article.

for localities at which fossils were collected. The numbers in italics are for the Canal Commission stations.

Section in canal cut 600 feet south of Miraflores Locks.

	Feet thick.
Pleistocene:	
3. River alluvium with gravel and pebbles, loosely cemented conglomerate at base, almost horizontally bedded, is unconformable on (2), and has an exposed thickness of...	20
Unconformity.	
Oligocene (Culebra formation):	
6009–2. Dark, soft, fairly well-laminated clay rock which seems to be unconformable on (1), shows a few lines of small limy concretions, buff-colored after weathering, parallel to the bedding. This is a foraminiferal clay and is the upper part of the lower beds of the Culebra formation. Dip 12° southward. Thickness exposed here.....	45
Unconformity.	
Eocene (?) (Las Cascadas agglomerate (?)):	
1. Mottled, light-greenish, fine-grained agglomerate to coarse tuff. The grains, one-eighth to 1 inch in diameter, are soft irregular particles of basic mud rock or much altered andesitic tuff. Finely divided chlorite seems to give greenish color. The spaces between the grains are filled with white limy cementing material, thus giving the rock a whitish and light-green mottled appearance, though the prevailing color is light green to grayish-green. Rock very similar in appearance to this is exposed in the upper part of the Contractors Hill mass, and was noted in the bottom of the Gaillard Cut near Paraiso, and near station *1909* where a small cave in the rock was found. As this lithologically resembles the Las Cascadas agglomerate and is distinctly different from the typical Culebra formation, it is considered as representing the upper part of the Las Cascadas agglomerate. Thickness exposed.....	15

Section at Canal Commission station 2089 south of Miraflores Locks.

	Feet thick.
Pleistocene:	
3. Silt and alluvium faulted down opposite (1), exposed about..	30+
Miocene (Panama formation):	
2. Light to buff-colored tuff beds showing some cross-bedding and some iron staining along the cracks, unconformable on (1), exposed about.....	15+
Eocene (?) (Las Cascadas agglomerate):	
1. Massive basic agglomerate, much altered, mostly greenish with some lighter-colored patches, giving a mottled color effect; cut by basaltic dikes; contains a few little cracks, some of which are filled with iron-stained cherty material. Exposed about.....	30+

There is at this place a fault which trends S. 15° E. and hades 80° W. It is impossible to estimate the amount of the throw, because it is not known how much may have been eroded from the upthrow side since faulting. In a few places along

Eocene—Continued.

the fault line springs bubble up, the waters from which were saline and astringent and gave off much carbon dioxide. This locality is now covered by the water in the canal.

Section, north end of Miraflores Locks.

Oligocene (Culebra formation):

At the north end of Miraflores Locks and from there to Pedro Miguel Locks, beds belonging in the lower part of the Culebra formation outcropped in the canal cut. They consist of dark, well laminated, and very soft carbonaceous clay rocks, and locally contain lenses of granular tufaceous material and a few beds that carry some pebbles. Some lines of small concretions parallel to the bedding were noted. Foraminifera common. In general, the beds have a dip of a few degrees toward the south, although one southward dip of 25 degrees was noted.

Section, Pedro Miguel Locks to Paraiso Bridge.

Oligocene (Culebra formation (lower part)):

6010. Material the same as in the preceding exposure. *Ostrea*, *Pecten*, and many Foraminifera, including *Lepidocyclina panamensis*?, were collected.

Section at Bald Hill near Miraflores Locks.

Total thickness of exposure about 325 feet; dip of beds 15° NW.

Oligocene:

	Feet thick.
Caimito formation—	
5. Limy, fine-grained sandstone, which weathers slightly buff-colored. A few fragments of fossils noted; outcrop indistinct. Estimated	60+
4. Dull yellowish, buff after weathering, rather soft and somewhat massively bedded, fine-grained sandstone. Estimated	80+
3. Limy agglomerate beds, light colored to brown, with a few greenish stains, similar to the blue and green stained beds that outcrop near San Pablo. Middle member of the Caimito formation. Estimated	65+
2. Light yellow to buff after weathering, fine-grained sandstone, fairly thick-bedded, but weathers rather platy or somewhat spherical. Lower part of the sandstone seems to be rather limy and weathers easily. Lower member of the Caimito formation. Estimated	80+
(There is some evidence of an unconformity between (2) and (1), but the contact is not clear enough to be sure of this.)	
Emperador limestone—	
6256–1. White to creamy gray, rather pure limestone; weathered surface much pitted; contains many fossil corals. Typical Emperador limestone. Estimated	40+

Section along east side of Gaillard Cut from Canal Commission stations 1848 to 1850.

Oligocene:

Cucuracha formation— Feet thick.

11. Material the same as No. 9. Exposed ..... 50+
10. Bed of fairly fine gravel, loosely cemented with calcareous material. Estimated 15
9. Light green, fine-grained, soft and friable argillaceous rock. Lower part of the Cucuracha formation. Estimated 50

Culebra formation—

8. Beds of partly consolidated gravel, with some dark-gray, granular, tufaceous material; light-colored, limy cement. Marks a small unconformity between the upper part of the Culebra formation and the overlying Cucuracha formation. Estimated 30

6011–7. Limy bed similar to No. 5; contains *Heterosteginoides panamensis* 5

6. Material similar to No. 4. Estimated 50
5. Fairly hard, somewhat coarse-grained, light-colored, sandy limestone grading into limy sandstone 5
4. Dark-gray, thin-bedded, friable tufaceous beds with partings of soft dark carbonaceous shales. Part of upper part of the Culebra and practically same as (2). Estimated 50
3. Two beds of gravel loosely cemented by light-colored limy cement. A 3-foot bed of dark, friable, carbonaceous shale separates the two gravel beds. Gravel contains a number of oysters and some other fossils. Appears to be a local unconformity here. Estimated thickness of gravel beds, including the shale bed 30
2. Thin-bedded, granular, and somewhat friable, dark-gray, tufaceous sandstone beds, separated by soft, dark-brown, carbonaceous shale layers; a few pebbles present. Part of the upper part of the Culebra formation. Dip about 35° northward. Estimated. 100

Age?

1. Laccolithic mass of basalt which has tilted the beds into which it was intruded and slightly metamorphosed them for a foot or more distant from the contact. A dike 1 to 3 feet wide seems to connect with main mass.

Section on west side of Gaillard Cut from Canal Commission stations 1775 to 1756.

Section shows three small faults, also contact between Cucuracha formation on top and Culebra formation beneath it. Thickness of entire section 400+ feet.

Oligocene:

Cucuracha formation—

2. Fine-grained, light-green, fairly massive volcanic clay rock. Feet thick.

f. Same as (*d*) 100
e. Andesite-breccia flow. About 20
d. Light-green, fairly massive, volcanic clay rock ..... 3 to 8
c. Small lens of limy sandstone. Maximum thickness about 1

	Feet thick
Oligocene—Continued.	
6012*e–b*. Dark-brown, carbonaceous shale with little lenses of lignite. Thickness irregular but maximum about	4
a. Lower part of formation, contains some sandy and pebbly layers	17+
Culebra formation—	
1. Dark friable carbonaceous shales and dark-gray granular tufaceous beds. A few thin lenses and beds that contain much gravel. Fossiliferous. Upper part of Culebra formation. Total thickness about	130
k. Loosely cemented gravel that seems to mark an unconformity between the Cucuracha formation on top and the Culebra formation below it. Some limy sandstone lenses at base of gravel	10–25
(Normal faults with a downthrow of 10 to 40 feet on the north side.)	
6012*d–j*. Few lenses of limy sandstone at base of gravel; *Lepidocyclina panamensis* ?	3
6013–*i*.[1] Friable shale and clay	35
6012*c–h*. Lens of sandy limestone	5
(Made special studies of and collections from the uppermost of these limestones and the shales between them. Found *Amphistegina* and *Lepidocyclina*, many oysters, and some *Turritella*.)	
g. Friable shale and clay	16
f. Limy sandstone	8
e. Friable shale and clay	10
d. Bed of light-colored, limy sandstone, similar to (*b*)	5
c. Bed of friable shale and clay	18
b. Lower bed of limy sandstone and sandy limestone. Light colored and fairly hard and well cemented. Fossiliferous	8
a. Lower layer of friable shale and clay	15

Section on west side of canal from Canal Commission station 1720, near Empire, to 1740 near Culebra.

(Total thickness of section, about 530 feet.)

	Feet thick.
8. Hard and finely cemented mass of dark andesitic tuff and breccia. Locally contains basalt fragments up to several inches in diameter, cemented into a mass. Rough bedding, with dip at a considerable angle, but formation generally massive.	
(Fault contact between (7) and (8) shows sheared zone several inches wide. Downthrow apparently on south side.)	
7. Light gray, buff after weathering, andesite breccia, a flow.	
6. Light-colored, fairly fine-grained, limy tuff, somewhat clayey; distinctly bedded	20
Oligocene (Culebra formation):	
5. *h*. Soil and, locally, old waste dump material. About	15
g. Bed of very loosely cemented gravel, somewhat weathered because of proximity to surface. About	20

[1] About this horizon but on east side of cut.

Oligocene—Continued.	Feet thick.
f. About same as (*d*)	40
e. About same as (*c*)	10
d. Dark, well laminated and very friable shale	35
c. Light-gray, limy sandstone and sandy limestone beds. Relatively hard and coarse grained. This limestone varies in thickness from 2 to 12 feet, which would seem to indicate a small unconformity along its top. Locally it contains some thin partings of carbonaceous shales	2 to 12
b. Lens of gravel up to 2 feet thick. Partly consolidated with limy cementing material. Oysters plentiful in this gravel.	
a. Dark, well laminated and very friable shale	30
4. Dark, well laminated and very friable shaly and tufaceous beds. Some of the layers less than an inch thick. Partings show fossil plants and much organic matter. Some of the layers weather brownish from organic matter. Between the more organic and clay-like layers are thin beds of dark-gray, granular to ash-like tufaceous material. Fossiliferous. Exposed	150
(Fault with a downthrow of more than 125 feet on the south side. Considerable shearing and disturbing of the beds for several feet on each side of the contact.)	
6012*b*–3. Light gray, limy gravel and some tufaceous material, not well bedded and only partly consolidated with limy cementing material. Fossils, particularly oyster shells, are plentiful. This bed seems to mark a local overlap or small unconformity	40
2. Dark-gray, bedded limy tuffs and partly consolidated shales. Differs from (5) in having more granular tufaceous material and less of the fine friable shale material. Is very limy, contains some gravel, and oyster shells are common	30
6012*a*–1. Dark, well laminated, soft, very friable, carbonaceous shales and dark-gray, granular, loosely cemented tuff beds. Typical lower Culebra beds. Fossil plants; marine fossils include *Lepidocyclina panamensis* ?, *Cyclichna*, *Conus*, *Pleurotoma* (3 species), *Arca*, *Pecten*, *Callianassa*, etc	150

Section on west side of Gaillard Cut near Las Cascadas, Canal Commission stations 1617 to 1597.

	Feet thick.
20. Yellowish to cream colored clays	15
Oligocene:	
Emperador limestone—	
6019*g*–19. Light gray to yellowish gray, somewhat sandy limestone. Massive, but some bedding in upper part. Very fossiliferous: *Pecten*, *Amusium*, *Stylophora*, *Clypeaster lanceolatus*, *Echinolampas semiorbis*, *Lepidocyclina*, etc	35

		Feet thick.
Oligocene—Continued.		
	Culebra formation—	
	18. Lignitic shale bed at base of limestone	2
	17. Dark, well laminated, very friable, carbonaceous shales and clays with dark, granular, tufaceous material. Fossils at base	30
6019*f*–	16. *c*. Light colored, sandy limestone. Thickness 1½	6
	b. Dark, very friable shales and tuffs. Fossils abundant, *Lepidocyclina chaperi*. Thickness 3	
	a. Light colored sandy limestone to limy sandstone. Thickness 1½	
	15. Dark, friable shale, clay and tufaceous material with some thin layers of limy sandstone in the upper part	10
6019*e*–14.	Thin-bedded, light-gray to cream-colored limy sandstone with some partings of light-colored clay, *Orbitolites*, etc	8
	13. Fine-grained, very friable, dark-gray, tufaceous material, well stratified	3
6019*d*–12.	*c*. Grayish-green, limy, tufaceous sandstones	3
	b. Dark, carbonaceous clays and tuff	1
6019*c*–	*a*. Grayish, well-stratified, and very friable tufaceous sandstone	3
	(Total thickness, 7 feet.)	
6019*b*–11.	Dark, well stratified, and very friable tufaceous material; some fossils. *Turritella*, *Arca*, *Cardium*, etc., *Orbitolites*	4
6019*a*–10.	Grayish, rather nodular, impure limestone, contains some green particles; *Lepidocyclina canellei* was collected in this bed	9
	9. Lignitic shale bed.....maximum..	3
	8. Dark-gray carbonaceous clays, friable shales and tuffs, some lines of limy nodules parallel to the bedding. Some of these concretions are as much as 6 inches thick and a foot long, their longer axes parallel to the bedding. One or two regular lines of these nodules near base	30
	7. Very friable lignitic shale bed.....maximum..	3
	6. Dark-gray carbonaceous clays, friable shales and tuffs. Lenses of limy nodules parallel to bedding, same as (8)	33
6020*c*	*c*. Just below the second line of nodules in these (6) beds fossils were found as follows: *Arca*, *Ostrea*, *Pecten*, *Spondylus*, etc. Among the fossil corals are *Orbicella*, *Siderastrea*, and *Goniopora;* one *Siderastra* head measured 20 inches high by 24 inches in horizontal diameter.	
6020*b*	*b*. A few feet below (*c*) found numerous cerithiids, *Nassa*, and *Corbula*.	
6020*a*	*a*. In the lower layers of this member of the section (No. 6) were found some poorly preserved mollusks, such as *Arca*, *Cardium*, *Tellina*, *Venus*, and fragments of crab claws in calcareous nodules.	

Oligocene—Continued.	Feet thick.
5. Friable, lignitic shale bed	2
4. Light-gray, limy-looking clay bed with some limy nodules and some lenses of soft nodular clayey limestone	6
3. Friable, lignitic shale bed	2
2. Light-gray to greenish fine-grained clay and fine agglomerate. Fairly massive	7
Unconformity.	
Eocene?	
Las Cascadas agglomerate:	
1. Dark-gray volcanic agglomerate	50
Total thickness	275

Section in cuttings of Panama Railroad near Caimito Junction.

Oligocene:

Emperador limestone—

	Feet thick.
6021 and **6673–4.** Light-gray to cream-colored, sandy limestone, *Lepidocyclina vaughani* abundant, also anullipore (*Lithothammium isthmi*) and numerous fragments of echinoid tests, including a *Clypeaster* (?). Strike N. 30° E., dip 20° N. 60° W.....About..	70
Unconformity.	
Bohio conglomerate—	
3. Fine argillaceous conglomerate; small pebble beds with sandy matrix, separated by clayey and sandy layers	20
2. Conglomerate, with gravel, cobbles, and small boulders; matrix clayey and sandy; fairly well bedded. Cobbles and boulders are mostly hornblende andesite and diorite	20
Unconformity.	
Eocene (?) (Las Cascadas agglomerate):	
1. Dark, massive, hard, and fairly well cemented andesitic agglomerate. Contains subangular fragments of andesite and basalt from a foot or more to less than an inch in diameter. Matrix fine dark andesite tuff.	
United States National Museum locality record station 6022 is on limestone about the same as (4), described above, a mile farther north.	

Railroad cut near stream about midway between Rio Frijol and Rio Frijolito.

Oligocene (Culebra formation):	Feet thick.
2. Surficial, residual red clay	15
6023. 1. Dark, very basic, friable, tufaceous material; *Lepidocyclina canellei* very abundant.....About..	25

Section in Railway Cuts Near New Frijoles.

Oligocene:

Emperador limestone— Feet thick.

6024*b*–5. Rio Agua Salud: Argillaceous, cream-colored limestone; fossil corals in base (*Stylophora*, *Acropora*, etc.), also *Pecten*, echinoids, etc. The limestone is bedded and has clay partings. Dip about 10° W..... 10

Culebra formation—

6024*a*–4. Rio Agua Salud: Dark, basic, tufaceous material, *Heterosteginoides panamensis*, *Nummulites panamensis*..... 10

Bohio conglomerate?—

3. Small pebble conglomerate, fairly well bedded..... 30

a. Fairly well-bedded conglomerate, with pebbles, cobbles, and boulders well rounded and in considerable variety but largely of hornblende-andesite and diorite facies. Largest boulders 2 feet in diameter. Matrix consists of sand, clay, etc. Dip 35° S..... 300

2. Dark, basic, orbitoidal, tufaceous material; bedding not distinct. Probably a part of Bohio conglomerate..... 20

b. Gray, thick-bedded, coarse-grained, somewhat basic, sandy, foraminiferal material. Dip 35° S. W. Roughly estimated at..... 400

a. Grayish, massive, argillaceous to sandy material; bedding not distinct. Probably part of Bohio conglomerate.....

Unconformity.

Eocene? (Las Cascadas agglomerate (?)):

1. Dark, fairly well cemented andesitic agglomerate; shows some rough bedding, contains subangular fragments of basalt and andesite from less than an inch to more than 2 feet in diameter. Matrix dark, fine-grained, andesitic tuff. Exposure behind New Frijoles railway station. Strike seems to be about N. 60° E., dip 30° W. Exposed..... 70

Section Showing Chief Railway Cuttings and Outcrops Along the Panama Railroa Between Bohio and Monte Lirio.

Miocene (Gatun formation (?)): Feet thick.

4. Monte Lirio: Fairly hard, sandy, drab-colored clay stone. Massively bedded and dipping about 7° northward; the clay weathers slightly buff-colored and contains white powdery particles like some of the clayey sandstone beds of the Gatun formation. No fossils found. Exposed..... 50

Oligocene:

Culebra formation (upper part)—

6025–3. *b*. Bohio switch: Light-colored, fairly coarse-grained, soft, somewhat limy sandstone with *Nummulites panamensis*, *Lepidocyclina chap-*

Oligocene—Continued.

Culebra formation—Continued. Feet thick.

eri, some echinoid fragments, also *Conus*, *Natica*, *Turritella*, *Pecten*, *Amusium*, *Lucina*, etc. This is probably the equivalent of the upper limy beds of the Culebra formation. Exposed..... 25

6026*a*. Two miles south of Monte Lirio: Somewhat coarse-grained sandstone which contains a few pebbles; massive, and weathers into large spherical masses; fossiliferous, *Stylophora* and other corals, *Lithothamnium vaughani*, *Lepidocyclina canellei*, *Nummulites panamensis?*, *Conus*, *Pecten*, *Ostrea*, etc. Seems to be nearly the same bed as 3*b*....

Bohio conglomerate—

2. *e–f*. Rather massive, soft, buff-weathing sandstone. No fossils noted. Slight dip southward. Exposed..... 20

Unconformity.

2. *a–d*. Railroad cuts which show exposures of conglomerate and sandy beds, dip about 7° northward.

Unconformity.

Eocene? (Las Cascadas agglomerate):

1. Dark, basic, andesitic agglomerate and breccia, showing some local overlaps; roughly bedded; dips 10° northward. (Fault zone here several feet wide trends N. 30° W. and dips 83° southward. Downthrow side on the south. Much sheared lignitic shale has been dragged into the fault zone. Some silicified wood found in the shale.)

Exposure a quarter of a mile northwest of old Bohio railroad station.

Oligocene (Culebra formation):

6027. Orbitoidal marl is exposed in the flat, the bottom of the canal, at the base of a hill that has been cut away. This is Hill's locality for "*Orbitoides forbesii*," which is *Lepidocyclina canellei*.

Exposure opposite old Bohio railroad station, north side of the railroad track.

Oligocene (Bohio conglomerate (?)):

A cliff about 75 feet high composed of dark-colored agglomerate of pyroclastic origin. This agglomerate is overlain at the second telegraph pole north of the 15th milepost from Colon by a small pebble conglomerate in a matrix of coarse, gritty sand.

Section at Peña Blanca, about 1 mile below Bohio, on the west side of Chagres River.

Oligocene (Bohio conglomerate)):

The entire hill is composed of dark-colored conglomerate of hornblende andesite porphyry pebbles, cobbles, and boulders embedded in coarse sand. No exposure of the orbitoidal marl was observed. Dip toward the northeast, 50 feet thick.

Section at Vamos à Vamos, 2½ miles below Bohio, west side of Chagres River.

Hill to the south across small ravine.

Miocene (Gatun formation):	Feet thick.
2. Yellowish sandstone and small pebble conglomerate.....	50
1. Dark bluish, fine-grained, argillaceous sandstone.....	
At and near landing, north side of the small ravine.	
6028*b*–2. Yellowish sandstone, some fossils.....	75
6028*a*–1. Dark-blue, argillaceous, fossiliferous sandstone, estimated.....	20

Fossils: *Cylichna*, *Turritella*, *Cardium*, etc. The exposure is rapidly becoming concealed by vegetation. Fossils were firmly embedded in the matrix and not easily removed.

Section on Panama Railroad from Monte Lirio to outcrop of Gatun formation on south side of Big Swamp.

5. Hill of basalt; quarried for facing material for Gatun dam.

Miocene (Gatun formation):	Feet thick.
6030–4. Bluish-gray, argillaceous beds which weather reddish; locally contain pebbles, fragments of organic matter, and many fossils. *Pecten*, *Clementia*, *Encope megatrema*, *Callianassa vaughani*. (This bed is exposed on the north side of the swamp, about 1½ miles north of Monte Lirio.) Dip about 10° northward.....	100
3. Fairly hard, sandy, drab-colored claystone; massively bedded and dips about 7° northward.....	50
Oligocene (Bohio conglomerate):	
2. Conglomerate, somewhat weathered and not extremely coarse; overlies sandstone, bedding not very clear.	
Local unconformity.	
1. Fairly coarse sandstone with a southward dip of about 20°.	

Section showing Gatun formation, one-quarter to one-half mile from Camp Cotton, toward Monte Lirio, at big curve on railroad.

Miocene (Gatun formation):	Feet thick.
7. Reddish soil.....	10
6029*c*–6. Bluish, fossiliferous argillite; contains some sandy beds and some lenses of buff-weathering, consolidated, impure fuller's earth.....	30
5. Bluish argillite, which weathers buff.....	9
4. Buff-weathering, consolidated, fuller's earth beds; not very pure.....	9
6029*d*–3. Bluish argillite.....	10
2. Buff-weathering, consolidated fuller's earth beds; not very pure.....	12
6029*a*–1. Bluish, fossiliferous argillite; some sandy and pebbly beds. *Encope platytata*, *Callianassa vaughani*, exposed.....	20
	100

Dip of all above beds about 7° northward. *Amphistegina lessonii* occurs in beds **6029***a*, *b*, and *c*.

Large railway cutting a quarter of a mile from Camp Cotton, toward Monte Lirio.

Miocene (Gatun formation):	Feet thick.
2. Dark-colored clay with white particles embedded in it...	
1. Dark-colored marl, fossils as at the two previous localities. Dip about 6° N. 60° W.....	

In the next two exposures going toward Camp Cotton.

2. Clay with white particles embedded in it.....	40 to 50
1. Dark-colored marl, fossiliferous.....	60

The lower beds exposed in the cutting one-half mile north of Camp Cotton are not exposed in the last-mentioned cutting.

Section in cut one-half mile west of Camp Cotton toward Gatun.

Miocene (Gatun formation):	Feet thick.
3. Marl, dark, blackish-gray when unweathered, brownish when weathered.....	15
2. Clay parting.....	2 or 3
1. Blackish-gray marl containing a conglomerate bed.....	35
This bed may be divided into three parts:	
603 *c*. Sandy marl.....	
b. Conglomerate bed.....	2 feet.
6032 *a*. Sandy marl with some pebbles.....	3 "

The lower bed of No. 1 (station 6032) contains fossils characteristic of the lower part of the Gatun formation.

Generalized section of the bluffs exposed along the Panama Railroad, relocated line, about 3,500 feet south of Gatun railroad station.

Miocene (Gatun formation):	Feet thick.
4. Fine-grained, buff clays (fuller's earth) with magnesian-looking spots.....	25
6033*d*–3. Fine-grained; soft, yellow sandstones.....	70
2. Buff, fine-grained, rather hard clay.....	25
1. 6033*c* –*c*. Dark-colored, marly, fossiliferous clay....	15–20
6033*b* –*b*. Yellowish clay.....	4
6033*a*, 6003 –*a*. Layer of dark, fossiliferous clay, exposed.	28

Section from top of hill at west end of Gatun dam to bottom of the spillway.

Pliocene (Toro limestone):	Feet thick.
6034–3. Top of hill, limestone. A rather soft coquina limestone composed of comminuted or broken tests of a number of kinds of organisms.....	70
Unconformity.	
Miocene (Gatun formation):	
2. Sandstone, surface oxidized brown.....	120
1. Dark-colored marl.....	35

Section at west end of the spillway.

2. Yellowish or brownish, sandy clay; soil red.....	20
5659, 5900 1. Dark-colored Gatun marl, with *Amusium*, *Clementia*, etc.....	16

Exposures in the vicinity of Mindi Hill.

Miocene (Gatun formation): Feet thick.

Gray-green, fine-grained, sandy shell marl is exposed from about 50 feet above sea level to 41 feet below; exposed thickness about 90 feet. The material occurs in beds 2 to 6 feet thick and is similar to that at the spillway. A number of fossils were collected from the exposures near the bottom of the canal **6035**.....

Near the railroad is an extensive Pleistocene shell bed from 6 to about 10 feet above sea level. Along the canal the Gatun formation is overlain by lignitic or peaty swamp deposits with occasional oysters.

Monkey Hill, Mount Hope station.

Miocene (Gatun formation):

6036. About one-sixth of a mile south of the station on the west side of the railroad is an exposure of dark-colored, fine-grained, sandy clay marl..... 20

North of Mount Hope Station, along the east side of the railroad on the north side of the cemetery, is the following exposure:

Miocene (Gatun formation):

2. Clay, light-gray, stiff, slightly sandy, with white particles of softer material, like the clay that overlies the marl near Camp Cotton on the relocated Panama Railroad.

1. Dark-colored, fine, sandy, clay marl, the same as that exposed at the locality immediately preceding.

Pleistocene reef-flat corals and other fossils occur 4 or 5 feet above sea level in a swamp north and east of Mount Hope and very near to the Colon road, **5850, 6038.**

Section of bluff at end of Toro Point.

Pliocene (Toro limestone):

Bedded coquina containing great numbers of barnacle plates, comminuted shells, and a large *Scala* (*Epitonium toroënse* Dall), forms a bluff 45 to 50 feet high. It is dark to light-gray in color, cross-bedded, and contains some lenses of coarse, basic beach sand. The beds dip about 5° northward. At the base of the bluff there is a fringe of coral-reef rock which has been slightly elevated. This material has been built around large masses of the Toro Point rock that have fallen from the bluff, so that they are now inclosed in a matrix of coral-reef rock which has been elevated perhaps 6 to 10 feet above the level at which it was originally formed. This marginal coral flat is from 200 feet to a quarter of a mile wide. Extensive flat swamps filled with mud and broken coral fragments fringe some of the higher land at Toro Point. These are up to half a mile or more wide and are about a foot, more or less, above high-tide level.

The coquina rock forming the bluff at Toro Point seems to be about the same as the coquina rock forming the top of the hill at the west end of Gatun Dam, except that the latter is light gray to creamy-white in color and is a purer limestone. This formation clearly overlies the Gatun formation and is

Pliocene—Continued.

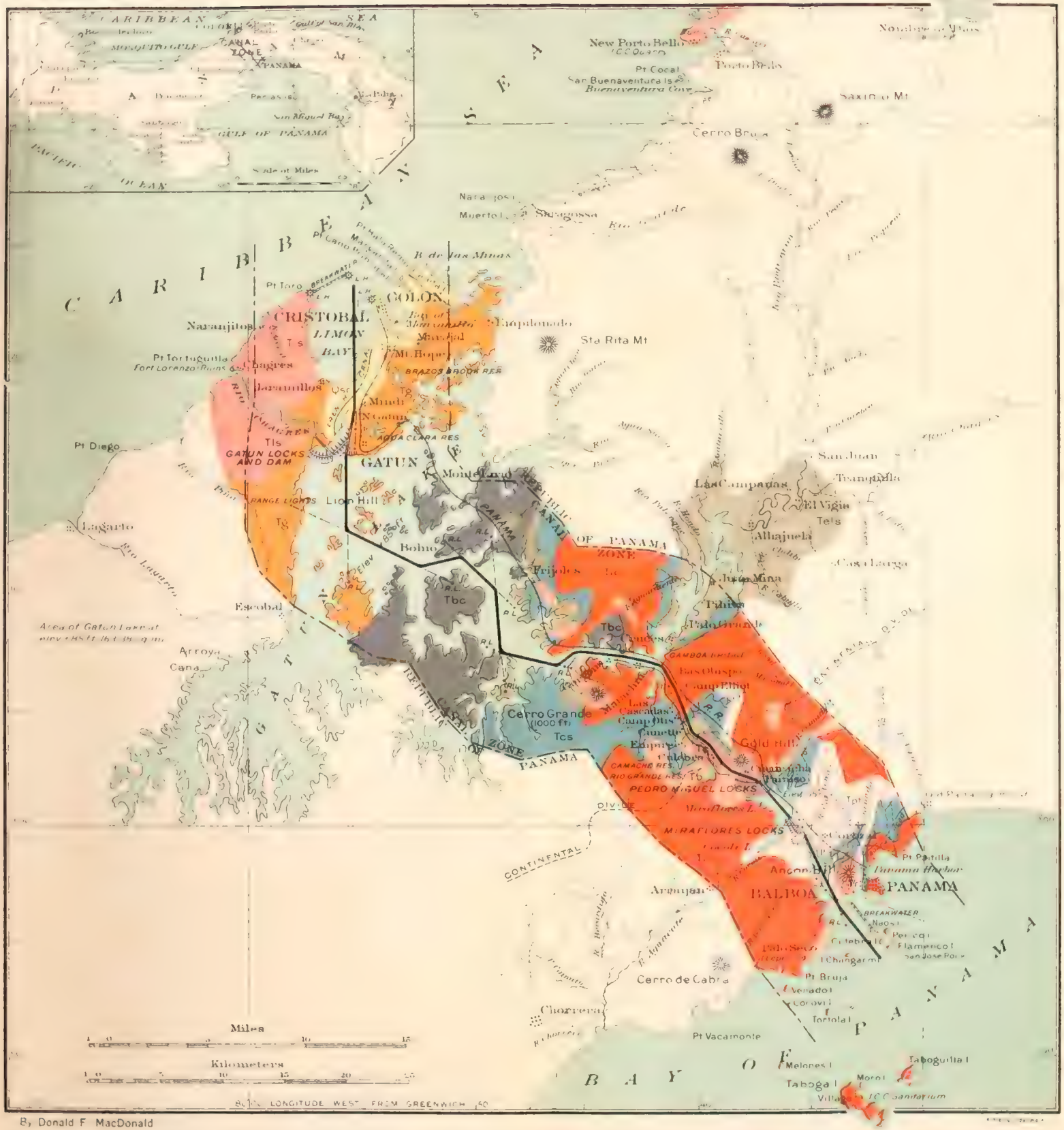
continuous westward into Costa Rica, except near the mouths of large river valleys where it has been removed or covered with alluvium. This coquina formation is clearly older than the marine Pleistocene (**5850**), occupying a level slightly above that of the sea, in the vicinity of Mindi, Mount Hope, and around the margins of Limon Bay. From the general stratigraphic relations of this rock I am inclined to consider it not younger than Pliocene.

Section one-third of a mile south of the southern end of Toro Point Breakwater, in quarry.

Feet thick.

6037. Gray coquina rock mixed with local layers and lenses of sand..... 35 to 40

Barnacle plates, echinoid spines, fragments of oyster shells, and a large *Scala* (*Epitonium toroënse* Dall) are abundant. Specimens of the last named form were the only perfect fossils found.



By Donald F. MacDonald
Base map by Isthmian Canal Commission

GENERALIZED GEOLOGIC MAP OF THE CANAL ZONE

TERTIARY

Qsc	Tls	Tpt	Tg	Tcs	Tels	Tc	Tbc	Tb	Tr	Ti
Swamps and coral flats	Toro limestone	Panama tuffs	Gatun formation	Caimito sandstone, tuffs, etc	Emperador limestone	Cucaracha and Culebra shales, tuffs and clay rocks	Bohio conglomerate and sandstone	Basalt and andesite	Rhyolite	Igneous complex, granodiorite, metabreccia, Las Cascadas agglomerate, Rio Obispo breccia, old tuffs (includes small areas of many of the other formations)
Pleistocene	Pliocene	Miocene				Oligocene		Miocene ?		

MAP OF THE PANAMA CANAL

SHOWING LOCATION OF STATIONS AT WHICH FOSSILS WERE COLLECTED

From map issued by the Isthmian Canal Commission
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CONTRIBUTIONS TO THE GEOLOGY AND PALEONTOLOGY OF THE CANAL ZONE, PANAMA, AND GEOLOGICALLY RELATED AREAS IN CENTRAL AMERICA AND THE WEST INDIES

THE BIOLOGIC CHARACTER AND GEOLOGIC CORRELATION OF THE SEDIMENTARY FORMATIONS OF PANAMA IN THEIR RELATION TO THE GEOLOGIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES

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THE BIOLOGIC CHARACTER AND GEOLOGIC CORRELATION OF THE SEDIMENTARY FORMATIONS OF PANAMA IN THEIR RELATION TO THE GEOLOGIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES.

By Thomas Wayland Vaughan,

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INTRODUCTION.

The following paper presents: (1) biologic summaries for each of the formations for which paleontologic data are available, with brief discussions of the geologic age; (2) geologic correlation of the formations and the distribution of their age-equivalents in Central America, the West Indies, and the southeastern United States; (3) an outline of the paleogeography of middle America. A tabular statement of the age relations of the formations is given by Doctor MacDonald in the preceding paper of this volume, page 528.

The biologic summaries are based on the paleontologic memoirs in this volume, by Messrs. Howe, Berry, Cushman, Jackson, Canu and Bassler, and Pilsbry, Miss Rathbun, and myself. Dr. C. W. Cooke has furnished me notes on a few of the fossil Mollusca, and I have incorporated in my lists the molluscan species recorded by Messrs. A. P. Brown and H. A. Pilsbry. I deeply regret that not even a preliminary list of the mollusks that Doctor MacDonald and I collected is available. Although I believe such a list would not modify the opinions here expressed, it is needed as a supplement to the other biologic records, particularly in order to supply a basis for the correlation of deposits in which mollusks are the only abundant organisms. I trust this serious omission may be remedied before a great while.

Needless to say all of the paleontologists who have studied the fossils submitted to them have cooperated in trying to solve the problems of local and regional geologic correlation, and I wish to record my grateful appreciation of their efforts. I wish also to thank my friend, Dr. T. W. Stanton, of the United States Geological Survey, for much advice and kindly criticism.

BIOLOGIC CHARACTER OF THE SEDIMENTARY FORMATIONS IN PANAMA.

Eocene.

The only geologic formation of Eocene age definitely recognized in Panama is exposed near Tonosi, Los Santos Province. At station

No. 6586*c*, near the mouth of Tonosi River, Doctor MacDonald collected a species of *Venericardia*, on which Dr. C. W. Cooke makes the following note: "A species of *Venericardia* from this locality is scarcely distinguishable from a specimen labeled *Venericardia planicosta* var. *horni* from Caliborne, Alabama, but it does not closely resemble specimens that I have seen from the Eocene of California, Washington, and Oregon." According to Doctor MacDonald's description of the section, this species of *Venericardia* occurs 690 feet below the bed in which *Lepidocyclina panamensis* Cushman and *L. duplicata* Cushman were collected. I believe that the latter bed is the correlative of the lower part of the Culebra formation, as will later be shown. Just below the Oligocene limestone in which occur the two species of Foraminifera mentioned are 650 feet of grayish, well-bedded, rather fine-grained sandstone; this is underlain by dark-gray, argillaceous, fossiliferous sandstone and shale, the latter underlain by dark-gray, argillaceous sandstone, in which the specimens of *Venericardia* were collected.

Doctor MacDonald collected the plant *Diospyros macdonaldi* Berry at station 6586*b*, in grayish, argillaceous sandstone with some darker shale beds, which immediately underlies the material in which the species of *Venericardia* occurs.

Dr. R. T. Jackson identifies as *Schizaster armiger* W. B. Clark, an echinoid collected by Mr. R. T. Hill at Bonilla, Costa Rica. The type of this species was obtained in a deposit of Jackson Eocene age at Cocoa post office, Choctaw County, Alabama. It should be noted that Mr. Hill says: "They [the rocks exposed] at Bonilla Cliff [Costa Rica] are upper Oligocene, like the Monkey Hill beds."[1] The determination of the Eocene age of this exposure is not positive.

On page 197 of this volume, in my paper on the fossil corals, I gave reasons for referring the typical part of the Brito formation of Nicaragua, that part exposed near Brito, to the upper Eocene, and correlated that part of the formation with the St. Bartholomew limestone of the Island of St. Bartholomew and the Jacksonian upper Eocene of the southeastern United States. The data and opinions referred to need not be repeated. The presence in northern Colombia of limestone containing small stellate *Orthophragmina*, indicating a probable upper Eocene, was also noted on page 197.

No fossil organisms were found in the Las Cascadas agglomerate or the Bas Obispo formation. As they both underlie the Bohio conglomerate, which is of Oligocene, probably lower Oligocene age, they are almost certainly of pre-Oligocene age. Although at present information is not available for precisely determining their age, it appears highly probable that they belong to the Eocene. However,

[1] Hill, R. T., The geological history of the Isthmus of Panama and portions of Costa Rica: Mus. Comp. Zool. Bull., vol. 28, p. 232, 1898.

Upper Cretaceous is not improbable as the age of the Bas Obispo formation.

Oligocene.

BOHIO CONGLOMERATE.

This is the oldest formation in which fossil organisms were found within the Canal Zone. The fossil plant, *Taenioxylon multiradiatum* Felix, collected in a railroad cut on Bohio Ridge, is said by Doctor MacDonald to come from the Bohio conglomerate. Should the specmens really come from the Bohio conglomerate, it is probable that that formation is of Oligocene age. *Taenioxylon multiradiatum*, according to Professor Berry, is also found in the Culebra and Cucuracha formations, both of which are of Oligocene age, should the Aquitanian be considered uppermost Oligocene instead of basal Miocene.

LIMESTONE ON HAUT CHAGRES.

H. Douvillé has published the following interesting note: "Un autre échantillon du Haut Chagres est representées par un calcaire plus compacte prenant bien le poli; il renforme également de petites Nummulites et de grandes Lépidocyclines voisines de *L. chaperi*, mais en outre, de petites Orbitoides qui sont des *Orthophragmina* étoilées (*Asterodiscus*). C'est la même association que celle que nous avons signalée à la base du stampien [=Lattorfian], dans l'île de la Trinité. . . Nous avons ainsi dans le Haut Chagres un niveau stampien inférieur." [1]

This corresponds to a horizon within the Vicksburg group. It is probable that the rocks underlying part of the area around Alahajuela mapped by Doctor MacDonald as Emperador limestone are really of this age.

LIMESTONE AT DAVID.

A similar forminiferal fauna occurs in the river bed, just above the ice plant in David, station 6512; at station 6526, which, according to Doctor MacDonald's section, is on the bed immediately next below the one exposed at station 6512; and at station 6523, 2 miles north of David. The following are the species reported by Doctor Cushman:

LARGER FORAMINIFERA FROM DAVID.

Name.	Station 6512.	Station 6526.	Station 6523.
Nummulites davidensis Cushman	×	×	
Lepidocyclina macdonaldi Cushman	×		×
duplicata Cushman	×		×
panamensis Cushman	×		
sp.		×	
Orthophragmina minima Cushman	×		
(*Asterodiscus*) sp.	×		

[1] Soc. géolog. France, Comptes rend. séance No. 16, 1915, p. 130, 1916.

Taenioxylon multiradiratum Felix was obtained at station 6523.

The limestone exposed at these three stations, which are all near one another, clearly belongs to one formation, and it seems to me to be of lower Oligocene (Lattorfian) age. However, Doctor Cushman because of the presence of *Orthophragmina minima* inclines to the opinion that it is of upper Eocene age.

Lepidocyclina duplicata was collected in association with *L. panamensis* at station 6586*e*, near Tonosi, in a bed I am considering of middle Oligocene (Rupelian) age (see p. 555).

CULEBRA FORMATION.

The principal localities at which collections were made from the Culebra formation were along the Canal from Miraflores locks to Las Cascadas. The local sections are described in Doctor MacDonald's article, pages 533 to 541 of this volume, and the position of each is indicated on plate 154. The United States National Museum station record numbers are 6009 to 6020*c*, as given at the column heads in the following table. Stations Nos. 6024*a*, 6025, 6026, are on the Panama Railroad, relocated line, and are platted on the map (pl. 154). Station No. 6837, on shales in the lower part of the Culebra formation, one-quarter of a mile south of Empire bridge, is not platted on the map.

The names of the specifically determined Mollusca from station No. 6019*a–d*, bed not identified, are taken from Brown and Pilsbry.[1] The specimens were obtained 65 and 85 feet below the "Pecten bed," which is the basal bed of the Emperador limestone. There are five of these species, only one of which, *Turritella altilira* Conrad, has been also reported from the Gatun formation. The generic names of the other Mollusca are mostly taken from my field notes. Doctor MacDonald and I obtained in the Culebra formation within Gaillard Cut, stations 6019*a–f* and 6020*a–c*, specimens representing about 70 genera of mollusks, but the species have not been identified.

Orthaulax pugnax (Heilprin), collected by Doctor MacDonald at station 5901, 2 miles south of Monte Lirio, formerly known as Mitchellville, was identified by Dr. C. W. Cooke. This is the same locality as station No. 6026, on the Panama Railroad, relocated line. *Lithothamnium vaughani*, *Nummulites panamensis*?, *Lepidocyclina canellei*, and three species of corals were also collected at this locality.

[1] Brown, A. P., and Pilsbry, H. A., Fauna of the Gatun formation, Isthmus of Pan amà—II, Acad. Nat. Sci. Phila. Proc. for 1912, pp. 502, 503, 1912.

Names.	6009	6010	6011	6012a	6012b	6012c–d	6019a	6019b	6019c	6019d	6019e–f	6020a	6020b–c	6024a	6025	6026	6027	6837	6839	Remarks.
PLANTAE.																				
Lithothamnium vaughani M. A. Howe.																×				
Ficus culebrensis Berry																		×		East wall, Gaillard Cut, north of Canal Com. station 1760.
Guatteria culebrensis Berry																				Do.
Myristocophyllum panamense Berry																				Do.
Taenioxylon multiradiatum Felix																				Top of big slide Gaillard Cut.
Inga oligocaenica Berry																		×		
Cassia culebrensis Berry																		×		
Banisteria praenuntia Berry																				West wall of canal below Miraflores locks.
Schmidelia bejucensis Berry																				East wall, Gaillard Cut, north of Canal Com. station 1760.
Mespilodaphne culebrensis Berry																				Do.
Melastomites miconoides Berry																				Do.
FORAMINIFERA.																				
Textularia laminata Cushman		×																		
agglutinans d'Orbigny							×													
sagittula Defrance															×	×				
Gaudryina flintii Cushman		×																		
triangularis Cushman		×																		
Clavulina parisiensis d'Orbigny		×																		
communis d'Orbigny		×																		
Lagena striata var. *strumosa* Reuss		×																		
Nodosaria insecta Schwager?		×																		
raphanistrum (Linnaeus)		×		×																
Cristellaria rotulata (Lamarck)		×		×		×														
protuberans Cushman		×																		
vaughani Cushman		×									×				×					
Siphogenerina raphanus var. *transversus* Cushman		×																		
Uvigerina pygmaea d'Orbigny						×	×													
Globigerina bulloides d'Orbigny	×	×									×									
inflata d'Orbigny		×																		
dubia Egger		×													×					

FOSSILS FROM THE CULEBRA FORMATION—continued.

Names.	6009	6010	6011	6012a	6012b	6012c–d	6019a	6019b	6019c	6019d	6019e–f	6020a	6020b–c	6024a	6025	6026	6027	6837	6839	Remarks.
Truncatulina ungeriana (d'Orbigny)	×			×																
wuellerstorfi (Schwager)		×				×														
culebrensis Cushman						×														
pygmaea Hantken										×										
americana Cushman											×									
Polystomella striato-punctata (Fichtel and Moll)												×			×					
craticulata (Fichtel and Moll)																				
Nonionina panamensis Cushman		×																		
anomalina Cushman		×																		
Amphistegina lessoni d'Orbigny	×			×		×			×	×										
Nummulites panamensis Cushman														×	×	(?)				
Lepidocyclina canellei Lemoine and Douvillé							×									×	×			Also at station 6891, Bailomonas, and station 6892, south of switch at Mamei.
chaperi Lem. and Douv.											×				×					
panamensis Cushman(?)		×		×		×														
Heterosteginoides panamensis Cushman.			×											×						
Quinqueloculina seminulum (Linnaeus) var.		×					×								×					
auberiana d'Orbigny															×					
Triloculina tricarinata d'Orbigny															×					
Orbitolites americana Cushman								×			×	×	×		×					
MADREPORARIA.																				
Stylophora imperatoris Vaughan																×				Also station No. 5863.
goethalsi Vaughan																×				
Orbicella costata (Duncan)													×							
Siderastrea conferta (Duncan)													×							
Astreopora antiguensis Vaughan																×				
Goniopora cascadensis Vaughan													×							
MOLLUSCA.																				
(Collections not yet identified.)																				
Cylichna sp				×																
Conus sp				×											×	×				

Pleurotoma				×																
Nassa (*Hima*) *scotti* Brown and Pilsbry.																				6019*a–d*.
sp.													×							
Orthaulax pugnax (Heilprin)																×				5901, 2 miles south of Monte Lirio.
Bittium scotti Brown and Pilsbry																				6019*a–d*.
Turritella altilira Conrad																				Do.
sp.					×	×									×					
Natica sp.															×					
Arca dalli Brown and Pilsbry																				6019*a–d*.
sp.				×		×						×	×							
Ostrea sp.		×		×	×								×			×				
Pecten sp.		×		×									×		×	×				
Amusium sp.															×					
Spondylus scotti Brown and Pilsbry																				6019*a–d*.
sp.																				
Cardium sp.						×						×								
Lucina sp.															×					
Tellina sp.												×								
Clementia sp.							×		×											
Corbula sp.													×							
CRUSTACEA.																				
Axius reticulatus Rathbun												×								
Callianassa lacunosa Rathbun				×																
sp.					×															
scotti Pilsbry							×													
vaughani Rathbun								(?)												6019*a–d*.
stridens Rathbun																				Do.
spinulosa Rathbun												×								Do.
quadrata Rathbun												×								Do.
ovalis Rathbun												×								
elongata Rathbun												×								
abbreviata Rathbun												×								
crassimana Rathbun												×								
magna Rathbun												×								
Goniochele (?) *armata* Rathbun												×								
Calapella quadrispinosa Rathbun												×								
Callinectes sp.					×															
sp.							×													
reticulatus Rathbun												×								
Euryplax culebrensis Rathbun					×															
Panopeus sp.							×													
Hepatus sp.								×												
Thamastoplax prima Rathbun												×								
Brachyrhyncha												×								
Mursia obscura Rathbun		×																		
Carpilius sp.															×					

The identification of deposits within the Canal Zone as belonging to the Culebra formation needs brief discussion. The type sections are in Gaillard Cut, particularly at station 6020*a* to 6019*f* (see p. 538 of Doctor MacDonald's paper), and beds Nos. 1–5, inclusive, of the section on the west side of the cut between Empire and Culebra. The collections from 6020*c* to 6019*f* are typical of the upper part of the formation; those from 6012*a* typify its lower part, while those from 6012*c* and 6012*d* represent its upper part (p. 536 of Doctor MacDonald's paper). He refers the beds that were exposed at stations 6009 and 6010 to the lower part of the Culebra, and those at stations 6011 to the upper part. In Gaillard Cut *Lepidocyclina chaperi* occurs at station 6019*f*, and *L. canellei* at station 6019*a;* in other words both of these species occur in the upper part of the Culebra formation, the latter below the former. *Heterosteginoides panamemsis* occurs at station 6011 in the upper part of the Culebra formation and apparently it was also obtained at stations 6015 and 6016 in the overlying Emperador limestone. As at station 6024*a*, on Rio Agua Salud, immediately beneath a coralliferous bed representing the Emperador limestone, *Heterostigenoides panamensis* and *Nummulites panamensis* were collected, both the stratigraphic relations and the fossils support the reference of the lower bed to the upper part of the Culebra formation. At Bohio switch, station 6025, *Lepidocyclina chaperi* and *Nummulites panamensis* were found in association. This bed also may be referred to the upper part of the Culebra formation. At station 6026, about 2 miles south of Monte Lirio, *Lepidocyclina canellei* and a species of *Nummulites*, apparently *N. panamensis*, were found associated with fossil corals closely related to the fauna of the Emperador limestone on one hand, and to that of the Antigua formation of Antigua on the other; and *Orthaulax pugnax* was collected there. The correlation of this exposure with the Culebra formation, probably about its middle part, seems as certain as it is possible to be in such matters. The principal locality for *Lepidocyclina canellei* was near the old town of Bohio, station 6027, now under water. It was here that Hill obtained his specimens of "*Orbitoides forbesi*," which are *L. canellei*, and it is probable that the type of the species came from the same place. The deposit here so rich in this species of Foraminifera is referred to the Culebra formation, as are also the beds in which it was obtained at Bailamonas and south of the switch at Mamei.

DEPOSITS OF THE AGE OF THE CULEBRA FORMATION NEAR TONOSI.

The only organisms of those collected by Doctor MacDonald in this area that have been studied are the Foraminifera and the corals. The following is a table of the larger Foraminifera:

LARGER FORAMINIFERA FROM NEAR TONOSI.

Name.	Station 6586*e*.	Station 6587.	Other stations.
Lepidocyclina panamensis Cushman	×	×	6010?, 6012*a*?, 6012*c*?, 6512.
duplicata Cushman	×	.....	6523.

Stations 6010, 6012*a*, and 6012*c* are along the Canal (see pl. 154), on the Culebra formation; station 6512 is the river bed in David and station 6523 is 2 miles north of David, on a limestone probably of lower Oligocene age. It therefore seems that *L. duplicata* is of both lower and middle Oligocene age, while *L. panamensis* occurs in lower, middle, and upper Oligocene deposits.

The following is a list of the corals collected by Doctor MacDonald near Tonosi:

FOSSIL CORALS FROM STATION 6587, TONOSI.

Name.	Distribution.
Astrocoenia guantanamensis Vaughan	Antigua; Cuba.
Favia macdonaldi Vaughan	Antigua.
Maeandra antiguensis Vaughan	Antigua.
Trochoseris meinzeri Vaughan	Cuba.
Diploastrea crassolamellata (Duncan)	Antigua; Cuba: etc.

The species after which Cuba is given in the column for distribution were collected by Mr. O. E. Meinzer near Guantanamo. These corals, which clearly belong to the coral fauna found in the Antigua formation of Antigua, supply additional evidence for correlating the foraminiferal limestones exposed at stations 6586*e* and 6587 with the lower part of the Culebra formation. By referring to my account of the successive coral faunas of the West Indies and Central America, pages 193 to 226 of this volume, it will be seen that, although I refer the coral fauna of the upper part of the Culebra formation to the upper Oligocene (=Aquitanian of European terminology), I consider that fauna as intermediate between the fauna of the Emperador limestone and Anguilla formation and that of the Antigua formation, because it contains a number of species in common with the latter formation. The coral fauna represented at Tonosi is, in my opinion, of middle Oligocene age, and belongs stratigraphically just below that found in the upper part of the Culebra formation.

CUCURACHA FORMATION

The only fossils as yet identified from the Cucuracha formation are two species of plants, *Palmoxylon palmacites* (Sprengel) Stenzel and *Taenioxylon multiradiatum* Felix, from station No. 6845, which is on the green clays of Gaillard Cut, near the lava flow. The first of these species was obtained only in the Cucuracha formation; but the second occurs in the Bohio conglomerate and the Culebra formation.

EMPERADOR LIMESTONE.

The type locality of this formation is in Empire village, and stations 6015 and 6016 are on it. As the two localities are very near together, with little or no lithologic or faunal difference, the fossils from the two localities are listed as from one in the following table. The position of the locality is shown on the map (pl. 154). Station 6017 is on the highway between Empire and Las Cascadas, about one mile from Las Cascadas. Nos. 6021 and 6673 are for the same locality, which is just north of Caimito switch, Panama Railroad, relocated line; station No. 6024*b* is on the same railroad, at the lower end of the culvert over Rio Agua Salud. Station No. 6255 is on the wagon road about one-half mile south of Miraflores; and station No. 6256 is Bald Hill, 1½ miles south of Miraflores (see p. 534 for Doctor MacDonald's description of the exposure).

The fossil plant, *Taenioxylon multiradiatum* Felix, was obtained at station 6523, which is about 2 miles north of David, where *Lepidocyclina macdonaldi* Cushman and *L. duplicata* Cushman were also collected. It is my belief that this specimen did not come from the Emperador limestone; for it is my opinion that the horizon is stratigraphically below the Culebra formation.

The specific names of the Mollusca and that of the echinoid, *Schizaster scherzeri* Gabb, from station No. 6019*g* are taken from the paper by Brown and Pilsbry already cited.[1] Doctor MacDonald and I obtained from the same bed species representing 32 genera of Mollusca, but they have not been identified.

Regarding the larger Foraminifera from stations 6015 and 6016, Dr. J. A. Cushman says: "The material from No. 6015 contains an orbitoid species, but the sections cut did not clearly reveal the internal structure. It has a papillate surface, and resembles *Lepidocyclina macdonaldi* and *L. panamensis*, but does not seem to be identical with either. Some of its characters, especially in its nearly diamond shaped chambers, it resembles *L. vaughani*, but the specimens of the latter are larger and they are not papillate. Although this appears to be a new species, I do not care to give a name to it without knowing its internal structure in greater detail, and suggest that it be listed as *Lepidocyclina* species.

"The material from No. 6016 apparently contains no orbitoids, but it contains *Amphistegina*, which superficially might be mistaken for an orbitoid."

Heterosteginoides sp., apparently *H. panamensis*, occurs at stations Nos. 6015 and 6016.

Lepidocyclina vaughani Cushman was obtained at two localities, stations Nos. 6021 and 6255.

[1] Acad. Nat. Sci. Phila. Proc. for 1912, p. 503.

The echinoid, *Clypeaster gatuni* Jackson, is worth a special note. The holotype is from the Gatun formation, station 5662, but two specimens were also collected at station 6237, in limestone referred by Doctor MacDonald to the Emperador limestone, in a swamp north of Ancon Hill and about 4 miles south of Diablo Ridge. This species extended from the Atlantic to the Pacific side of the Isthmus.

Doctor MacDonald and I obtained at station No. 6019*g* two poor crushed specimens of a gastropod that belongs to the genus *Orthaulax*.

A few remarks should be made on the reference of the limestone exposed at station 6021 near the old Caimito switch, to Emperador limestone. Only two identifiable species, *Lithothammium isthmi* and *Lepidocyclina vaughani*, were obtained at this place, but both were found elsewhere in the Emperador limestone. *Lithothammium isthmi* was also collected on Rio Agua Salud, station 6024*b*, in association with a coral fauna very nearly the same as that at the type locality of the formation; and *Lepidocyclina vaughani* was obtained in the Emperador limestone near Miraflores.

FOSSILS FROM THE EMPERADOR LIMESTONE.

	6015, 6016	6017	5866*b*, 6019*g*, 6671	6021, 6673	6024*b*	6255	6256
PLANTAE.							
Lithothammium isthmi M.A. Howe				×	×		
FORAMINIFERA.							
Polystomella macella (Fichtel and Moll)	×						
Amphistegina lessonii d'Orbigny	×						
Lepidocyclina sp.	×						
sp.			×				
vaughani Cushman				×		×	
Heterosteginoides sp., apparently *H. panamensis* Cushman	×						
Quinqueloculina undosa Karrer	×						
MADREPORARIA.							
Stylophora imperatoris Vaughan	×				×		
panamensis Vaughan	×						
goethalsi Vaughan	×						
macdonaldi Vaughan	×				×		
canalis Vaughan	×						
Pocillopora arnoldi Vaughan	×						
Astrocoenia portoricensis Vaughan					×		
Orbicella imperatoris Vaughan	×	×					×
canalis Vaughan	×						
Stylangia panamensis Vaughan	×						
Goniastrea canalis Vaughan	×						
Favona panamensis Vaughan	×						
Tricropora panamensis Vaughan					×		
saludensis Vaughan	×				×		
Astreopora goethalsi Vaughan	×						
Goniopora hilli Vaughan	×						
panamensis Vaughan	×						
imperatoris Vaughan	×						
canalis Vaughan	×						
clevei Vaughan	×						
Porites douvillei Vaughan	×						
toulai Vaughan	×						
panamensis Vaughan	×						
anguillensis Vaughan	×						
(*Synaraea*) *howei* Vaughan	×						
macdonaldi Vaughan	×						

FOSSILS FROM THE EMPERADOR LIMESTONE—continued.

	6015, 6016	6017	5866*b*, 6019*g*, 6671	6021, 6673	6024*b*	6255	6256
ECHINOIDEA.							
Clypeaster lanceolatus Cotteau			×				
gatuni Jackson							
Echinolampas semiorbis Guppy			×				
Schizaster scherzeri Gabb			×				
BRYOZOA.							
Holoporella albirostris (Smitt)	×						
Ogivalina mutabilis Canu and Bassler	×						
MOLLUSCA.							
Murex (*Phyllonotus*) *gatunensis* Brown and Pilsbry			×				
Orthaulax sp			×				
Pyrula micronematica Brown and Pilsbry			×				
Arca sp			×				
Ostrea gatunensis Brown and Pilsbry			×				
Pecten (*Aequipecten*) *ozygonum canalis* Brown and Pilsbry			×				
sp	×						
Amusium sol Brown and Pilsbry			×				
sp			×				
sp	×						
Tellina vetula Brown and Pilsbry			×				
Semele chipolana Dall			×				
Chione (*Lirophora*) *ulocyma* Dall			×				
Dosinia delicatissima Brown and Pilsbry			×				
Crassatillites mediamericana Brown and Pilsbry			×				
Kuphus incrassatus Gabb			×				
CRUSTACEA.							
Macrobrachium, sp			×				
Callianassa tenuis Rathbun			×				
Mursia macdonaldi Rathbun			×				
Parthenope panamensis Rathbun			×				

CAIMITO FORMATION.

No fossils were obtained in this formation at its type locality. Doctor MacDonald collected fossil plants at station No. 6840, about 7 miles northeast of Bejuca, near Chame, Panama, in a yellowish. argillaceous sandstone that seems to overlap agglomerates and is believed to represent the Caimito formation. Professor Berry records the following species from this locality:

Guatteria culebrensis Berry, also Culebra and Gatun formations.

Hiraea oligocaenica Berry.

Hieronymia lehmanni Berry.

Schmidelia bejucensis Berry, also Culebra formation.

As two of the four species also occur in the Culebra formation, it appears that the deposit in which they were obtained is in age near the Culebra formation.

MIOCENE.

GATUN FORMATION.

The principal collections from the Gatun formation were made jointly by Doctor MacDonald and myself at stations Nos. 6029*a*–*b*, 6030, 6033*b*–*c*, 6035, and 6036, the position of each of which is platted on the map (pl. 154), and the sections are described in Doctor Mac-

Donald's article, pages 542–544 of this volume. Four species of plants were collected in the Gatun borrow pits. No. 6003 is for the same bed as 6033*b*. Station No. 5659 is near Gatun. The localities for three of the species of Crustacea are as follows:

Gatunia proavita Rathbun, Cat. No. 113706, U.S.N.M., near Gatun.

Callianassa hilli Rathbun, Cat. No. 135218, U.S.N.M., Gatun formation; nothing more definite.

Mursilia ecristata Rathbun, Cat. No. 135219, U.S.N.M. Gatun formation; nothing more definite.

FOSSILS, EXCEPT MOLLUSCA, FROM THE GATUN FORMATION.

	Gatun borrow pits.	5900, Gatun locks.	6029*a*.	6029*b*.	6030.	6033*b*, 6003.	6033*c*.	6035.	6036.
PLANTAE.									
Guatteria culebrensis Berry	×								
Calyptranthes gatunensis Berry	×								
Rondeletia goldmani Berry	×								
Rubiacites izoreoides Berry	×								
FORAMINIFERA.									
Textularia subagglutinans Cushman							×		
panamensis Cushman							×		×
carinata d'Orbigny									×
Chrysalidina pulchella Cushman									×
Bolivina punctata d'Orbigny							×	×	
aenariensis (Costa)							×		×
robusta H. B. Brady								×	
Bigenerina nodosaria d'Orbigny									×
Virgulina squamosa d'Orbigny							×	×	×
Nodosaria communis d'Orbigny									×
Cristellaria rotulata (Lamarck)							×	×	×
vaughani Cushman								×	×
italica Defrance									×
Uvigerina canariensis d'Orbigny								×	
pygmaea d'Orbigny								×	
tenuistriata Reuss									×
Globigerina bulloides d'Orbigny				×			×	×	×
dubia Egger							×	×	×
sacculifera H. B. Brady							×	×	×
aequilateralis H. B. Brady							×	×	×
inflata d'Orbigny								×	×
conglobata H. B. Brady								×	×
Orbulina universa d'Orbigny								×	×
Pulvinulina menardii d'Orbigny							×	×	×
oblonga (Williamson)								×	
concentrica Parker and Jones								×	
Polystomella striatopunctata (Fichtel and Moll)			×						
crispa (Linnaeus)				×					
Nonionina depressula (Walker and Jacobs)							×	×	
scapha (Fichtel and Moll)							×		
Amphistegina lessonii d'Orbigny			×	[1]×					
Siphonina reticulata (Czizek)									×
Quinqueloculina seminulum (Linnaeus)									×
panamensis Cushman									×
Sigmoilina tenuis Czizek							×	×	×
asperula (Karrer)								×	×
Triloculina bulbosa Cushman			×		×				
projecta Cushman								×	
Biloculina bulloides d'Orbigny									×
ECHINOIDEA.									
Clypeaster gatuni Jackson (Sta. 5662)									
Encope annectans Jackson (Sta. 5846)									
platytata Jackson			×						
megatrema Jackson					×				
Schizaster panamensis Jackson (Stas. 6008, 7294)									

[1] Also 6029*c*.

FOSSILS, EXCEPT MOLLUSCA, FROM THE GATUN FORMATION—continued.

	Gatun borrow pits.	5900, Gatun locks.	6029a.	6029b.	6030.	6033b, 6003.	6033c.	6035.	6036.
MOLLUSCA.									
(See next following list.)									
CRUSTACEA.									
Callianassa vaughani Rathbun			×		×				
crassa Rathbun						×			
hilli Rathbun						×			
(?) sp.									
Gatunia proavita Rathbun (also Sta. 5659)		×			×				
Mursilia ecristata Rathbun									
Balanus concavus Bronn					×				
Lepas injudicata Pilsbry						×			
SELACHII.									
Carcharias sp. (Sta. 5899)									
Lamna cf. *L. elegans*			×						
Charcharodon cf. *C. auriculatus*			×	×	×				

MOLLUSCA FROM THE GATUN FORMATION, ACCORDING TO BROWN AND PILSBRY.[1]

The collections, mostly Mollusca, considered in the first paper by these authors, "with the exception of a tooth of a shark and a few specimens of *Oliva* from Monkey Hill, all come from the excavations for the locks at Gatun. The *Oliva* taken at Monkey Hill is the same species found plentifully at the Gatun excavation. The specimens were collected from dumps and fills along the railway as well as from dumps in the vicinity of Gatun." In their second paper, collections from other localities near Gatun and from two horizons at Tower N, Las Cascadas, are included. The following list contains all the mollusca referred to the Gatun formation by Pilsbry and Brown. The names of those preceded by an asterisk were not in the collections submitted to those authors, and I have added the note "not at Gatun" after the names of those which were not collected at Gatun. The results of our field work and the subsequent paleontologic studies cause us to dissent from the stratigraphic interpretations of Messrs. Brown and Pilsbry, for they combine the Culebra formation, the Emperador limestone, and the Gatun formation into one formation. As the species described by Toula in his Eine jungteriäre Fauna von Gatun am Panama-Kanal[2] are included in the papers by Brown and Pilsbry, more detailed reference to his article is not necessary here.

[1] Brown, Amos P., and Pilsbry, Henry A., Fauna of the Gatun formation, Isthmus of Panama: Acad. Nat. Sci. Phila. Proc. for 1911, pp. 336-373, pls. 22-29, April, 1911; Fauna of the Gatun formation—II, idem, for 1912, pp. 500-519, pls. 22-26. December, 1912.

[2] K. K. Geol. Reichsanstalt Jahrb., vol. 58, pp. 673-760, pls. 25-28, Vienna, 1909. Toula in a second paper, Die jungtertiare Fauna von Gatun am Panama-kanal, K. K. Geolog. Reichsanstalt Jahrb., vol. 61, pp. 487-530, pls. 30, 31, Vienna, 1911, published a supplement to his first paper issued in 1910, and the species described as new in this are not included in the papers by Brown and Pilsbry. This one of Toula's papers escaped my attention until the present volume was in proof, and as it was then too late to consider the synonymy of the species described in it, remarks on it are confined to this note.

**Bullina chipolana* Dall.
Volvulella micratracta Brown and Pilsbry.
Rigicula hypograpta Brown and Pilsbry.
Terebra subsulcifera Brown and Pilsbry.
gatunensis Toula.
wolfgangi Toula.
gausapata Brown and Pilsbry.
Conus concavitectum Brown and Pilsbry.
haytensis Sowerby.
domingensis Sowerby (?).
consobrinus Sowerby.
granozonatus Guppy.
aemulator Brown and Pilsbry.
imitator Brown and Pilsbry.
gaza Johnson and Pilsbry.
molis Brown and Pilsbry.
Pleurotoma albida Perry.
**Pleurotoma gertrudis* Toula.
vaningeni Brown and Pilsbry
Drillia gatunensis Toula.
isthmica Brown and Pilsbry.
fusinus Brown and Pilsbry.
zooki Brown and Pilsbry.
consors (Sowerby).
enneacyma Brown and Pilsbry.
Cythara heptagona (Gabb).
Cancellaria dariena Toula.
decaptyx Brown and Pilsbry.
Mitra longa Gabb.
dariensis Brown and Pilsbry
sp. undet.
Marginella gatunensis Brown and Pilsbry.
leander Brown and Pilsbry.
coniformis Sowerby.
Oliva reticulata gatunensis Toula.
Fasciolaria gorgasiana Brown and Pilsbry.
sp. undet.
**Glyptostyla panamensis* Dall (not at Gatun).
Solenosteira dalli Brown and Pilsbry.
Phos gatunensis Toula.
subsemicostatus Brown and Pilsbry.
metuloides Dall.
Metula gabbi Brown and Pilsbry.
Nassa (*Hima*) *praeambigua* Brown and Pilsbry (not at Gatun).
Anachis fugax Brown and Pilsbry.
**Strombina mira* Dall.
lessepsiana Brown and Pilsbry.
Murex messorius Sowerby.
polynematicus Brown and Pilsbry.
(*Phyllonotus*) *gatunensis* Brown and Pilsbry.
Typhis alatus Sowerby.
gabbi Brown and Pilsbry.
Strombus gatunensis Toula.
(?) sp. undet.
Distorsio gatunensis Toula.
Malea camura Guppy.
Sconsia laevigata (Sowerby).
Pyrula micronematica Brown and Pilsbry (not at Gatun).
near *papyratia* Say.
Cypraea henekeni Sowerby var.
Bittium nugatorium Brown and Pilsbry.
scotti Brown and Pilsbry (not at Gatun).
Turbonilla bartschiana Brown and Pilsbry.
Turritella mimetes Brown and Pilsbry.
gatunensis Conrad.
altilira Conrad.
Petaloconchus domingensis Sowerby.
Solarium granulatum gatunensis Toula.
Natica guppyana Toula.
bolus Brown and Pilsbry.
canrena (Linnaeus).
canalizonalis Brown and Pilsbry.
(?) sp. undet.
Polinices subclausa (Sowerby).
**Lupia perovata* Conrad (not at Gatun).
Sigaretus gatunensis Toula.
(*Eunaticina*) *gabbi* Brown and Pilsbry.
**Capulus* (?) *gatunensis* Toula.
Crepidula plana Say.
Cheilea princetonia Brown and Pilsbry.
Nucula (*Acila*) *isthmica* Brown and Pilsbry
Leda balboae Brown and Pilsbry.
Arca dariensis Brown and Pilsbry.
dalli Brown and Pilsbry (not at Gatun).
Glycymeris carbasina Brown and Pilsbry.
canalis Brown and Pilsbry.
acuticostata Sowerby.
Pecten (*Æquipecten*) *effosus* Brown and Pilsbry.
gatunensis Toula.
(*Plagioctenium*) *operculariformis* Toula.
**Pecten levicostatus* Toula.
(*Euvola*) *reliquus* Brown and Pilsbry.
oxygonum canalis Brown and Pilsbry (not at Gatun).
oxygonum optimum Brown and Pilsbry (occurrence at Gatun doubtful).

Pecten (Cyclopecten) oligolepis Brown and Pilsbry.
**(Amusium) lyonii* Gabb.
toulae Brown and Pilsbry.
sol Brown and Pilsbry (not at Gatun).
luna Brown and Pilsbry.
Spondylus scotti Brown and Pilsbry (not at Gatun).
Ostrea gatunensis Brown and Pilsbry.
Crassatellites reevei (Gabb) (occurrence at Gatun doubtful).
mediaamericanus Brown and Pilsbry (not at Gatun).
Cardium (Trachycardium) stiriatum Brown and Pilsbry.
**dominicanum* Dall.
dominicense Gabb.
durum Brown and Pilsbry.
Cardium (Laevicardium) serratum Linnaeus.
**dalli* Toula.
**(Fragum) gatunense* Dall.
(?) *newberryanum* Gabb.
**Tellina dariena* Gabb.
**gatunensis* Bagg.
**rowlandi* Toula.
**lepidota* Dall.
aequiterminata Brown and Pilsbry.
(Eurytellina) vetula Brown and Pilsbry (not at Gatun).
sp. undet.
sp. undet.
**Semele sayi* Toula.
chipolana Dall (not at Gatun).
Chione tegulum Brown and Pilsbry.
sp. undet.
(Lirophora) ulocyma Dall.
ulocyma holocyma Brown and Pilsbry.
**mactropsis* (Conrad).
Pitar centangulata Brown and Pilsbry.
cora Brown and Pilsbry.
**hilli* Dall.
**circinata* (Brown).
** Macrocallista maculata* (Linnaeus) (?).
Dosinia delicatissima Brown and Pilsbry.
**Callocardia (Agriopoma) gatunensis* Dall.
**gatunensis multifilosa* Dall.
Petricola millestriata Brown and Pilsbry.
Clementia dariena (Conrad).
Cyclinella gatunensis Dall.
**Mactra dariensis* Dall (not at Gatun).
Thracia (Cyathodonta) gatunensis Toula.
Corbula gatunensis Toula.
sphenia Dall.
sericea Dall.
(Cuneocorbula) hexacyma Brown and Pilsbry.
**alabamiensis* Lea.
**gregorioi* Cossmann.
heterogenea Guppy (not at Gatun).
**viminea* Guppy (not at Gatun).
Teredo dendrolestes Brown and Pilsbry.
**Solecurtus gatunensis* Toula.
strigillatus (Linnaeus).

Sixteen species included in the foregoing list have not been found at Gatun, and the occurrence there of two other species is doubtful. The number of identified species of mollusca from the formation, including two doubtfully determined, is 125.

Subsequent to the publication of the papers by Brown and Pilsbry, Cossmann[1] has described four additional species from Mindi out of materal belonging to the Gatun formation. The species are as follows: *Euchilodon moierei* Cossmann; *Conus lavillei* Cossmann; *Uxia miocaenica* Cossmann; *Marginella mindiensis* Cossmann.

Pliocene.

Toro limestone.

At Toro Point, the type locality of this formation, station No. 6037, Doctor MacDonald and I collected the types of *Epitonium* (*Sthe-*

[1] Cossmann, M., Étude comparative de fossiles miocèniques recueillis à la Martinique et à l'Isthme de Panama, Journ. Conchyl., vol. 61, pp. 1–64, pls. 1–5, 1913.

norytis) toroënse Dall and of *E. toroënses* var. *insigne* Dall.[1] In addition to these identifiable Mollusca, dissociated barnacle plates and comminuted milliscan shell fragments are abundant. The probably equivalence of this deposit with the coquina rock, which contains many fragments of *Pecten* sp., on the top of the hill at the west end of Gatun dam, is discussed by Doctor MacDonald on page 544 of his article immediately preceding the present one.

Pleistocene.

Although horizons in the marine Pleistocene deposits of America have not yet been discriminated on the basis of their contained fossils, it is my opinion that such discriminations will be made. As a contribution toward the biologic characterization of a Pleistocene deposit, the following list of fossils from the deposit in the swamp north and east of Mount Hope, stations Nos. 5850 and 6038, has been prepared. Two papers on the fossil mollusca from this locality have been published. The first is by Dr. W. H. Dall, in his paper just referred to; the second is by Messrs. Brown and Pilsbry.[2] The other lists are from the memoirs forming parts of this volume.

FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE.

PLANTAE.

Archaeolithothamnium episporum M. A. Howe.

MADREPORARIA.

Oculina diffusa Lamarck.
varicosa Le Sueur.
Eusmilia fastigiata (Pallas).
Astrangia (Phyllangia) americana Milne Edwards and Haime.
Cladocora arbuscula Le Sueur.
Solenastrea bournoni Milne Edwards and Haime.
Favia fragum (Esper).
Maeandra areolata (Linnaeus).
Manicina gyrosa (Ellis and Solander).
Agaricia agaricites (Linnaeus).
var. *purpurea* Le Sueur.
pusilla Verrill.
Siderastrea radians (Pallas).
siderea (Ellis and Solander).
Acropora muricata (Linnaeus.)
Porites furcata Lamarck.
astreoides Lamarck.

HYDROZOA.

Millepora alcicornis Linnaeus.

MOLLUSCA.

Tornatina canaliculata (Say). R.[3]
Cylichnella bidentata (Orbigny.)
Atys sandersoni Dall.
Bullaria occidentalis (A. Adams). C.
Haminea canalis Dall.
Haminea antillarum (Orbigny). R.
Terebra spei Brown and Pilsbry.
Conus proteus Hwass. R.
Drillia leucocyma Dall.
ostrearum Stearns.
harfordiana (Reeve) var. *colonensis* Brown and Pilsbry. R.
Clathurella jewetti Stearns. R.
Cythara balteata (Reeve).
biconica (C. B. Adams). C.
Marinula colonia Dall. R.
Olivella myrmecoon Dall. C.
Marginella cincta Kiener C.
pallida (Linnaeus). R.
minuta Pfeiffer.

[1] Dall, W. H., New species of fossil shells from Panama and Costa Rica, Smithsonian Misc. Coll., vol. 59, No. 2, pp. 6, 7, 1912.

[2] Brown, A. P., and Pilsbry, H. A., Two collections of Pleistocene fossils from the Isthmus of Panama, Acad. Nat. Sci. Phila. Proc. for 1913, pp. 493–500, 1913.

[3] The abundance or rarity of the species is indicated by the letters R. (rare) and C. (common).

FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE—continued.

MOLLUSCA—continued.

Voluta alfaroi Dall. R.
Fasciolaria species. R. Specimen too young to determine.
Latirus cingulifera (Lamarck). R.
Phos intricatus Dall. R.
Engina turbinella (Kiener). R.
Nassa vibex Say.
Columbella mercatoria (Linnaeus).
Anachis avara (Say). R.
samanensis Dall. C.
pulchella (Kiener). R.
Aspella scalaroides (Blainville). R.
Strombus bituberculatus Lamarck.
pugilis Linnaeus.
Trivia pediculus (Linnaeus). R.
Murex rufus Lamarck. R.
pomum Gmelin.
nodatus Reeve. C.
Urosalpinx species. R.
Eulima bifasciata (Orbigny). R.
Cymatium vespaceum (Lamarck). R.
tuberosum (Lamarck). R.
Cerithiopsis species. R.
Bittium varium Pfeiffer. C.
Cerithium literatum (Born). R.
algicola C. B. Adams. C.
medium Dall. R.
variabile C. B. Adams.
Cerithidea varicosa Sowerby. R.
Modulus modulus (Linnaeus). C.
catenulatus Philippi. R.
Littorina angulifera Lamarck. R
Vermetus nigricans Philippi (?). R.
Alabina cerithoides Dall.
Alaba tervaricosa Adams. R.
Rissoina laevigata C. B. Adams var.
browniana Orbigny.
striatocostata Orbigny. R.
cancellata Philippi. R.
elegantissima Orbigny. R.
Crepidula convexa Say. C.
plana Say. C.
Calyptraea candeana Orbigny. C.
Natica pusilla Say. R.
Sigaretus perspectivus Say. R.
Phasianella pulchella C. B. Adams. C.
Turbo crenulatus Gmelin. R.
Astralium brevispina (Lamarck). R.
tuberosum (Philippi) (?)
Tegula fasciata (Born).
Fissuridea alternata (Say).
Subemarginula emarginata (Blainville).
rollandii (Fischer).

MOLLUSCA—continued.

Acmaea punctata (Gmelin).
Neritina viridis Lamarck. C.
Tonicia schrammi Shuttlworth. R.
Dentalium callithrix Dall. C.
Cadulus vaughani Dall. C.
Leda vulgaris, new species. C.
acuta Conrad. R.
Yoldia perprotracta Dall. C.
Arca umbonata Lamarck. R.
imbricata Brugière. R.
antiquata Linnaeus. C.
deshayesi Hanley. C.
campechiensis Dillwyn. R.
adamsi Smith.
occidentalis Philippi. R.
reticulata Gmelin. R.
Scapharca pittieri Dall. C.
Byssoarca fusca Brugière. C.
Melina ephippium (Linnaeus). C.
Ostrea virginica Gmelin. C.
Pecten ziczac (Linnaeus). C.
exasperatus Sowerby. C.
gibbus (Linnaeus).
gibbus dislocatus Say. R.
Mytilus exustus Lamarck. R.
Chama sp. R.
sp. C.
Crassinella guadalupensis (Orbigny). R.
Diplodonta mediamericana Brown and Pilsbry. R.
Diplodonta soror C. B. Adams. C.
Codakia orbiculata (Montagu). R.
antillarum Reeve. C.
Lucina chrysostoma Philippi. C.
Phacoides lintea (Conrad). R.
near *crenulatus* (Conrad). R.
antillarum Reeve. R.
leucocyma Dall. R.
pectinatus (Gmelin). C.
Phacoides species
Cuspidaria (*Cardiomya*) *costellata* Deshayes. R.
Cardium serratum Linnaeus. C.
medium Linnaeus.
muricatum Linnaeus. C.
Gafrarium (*Gouldia*) *cerina* (C. B. Adams). R.
Pitar subarresta Dall.
Chione cancellata (Linnaeus). C.
Tellina (*Eurytellina*) *alternata* Say. C.
(*Cyclotellina*) *fausta* Donovan.
(*Angulus*) *versicolor* Cozzens.
promera Dall.

FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE—continued.

MOLLUSCA—continued.

Abra aequalis (Say). R.
Corbula equivalvis Philippi. C.
swiftiana C. B. Adams C.

CRUSTACEA.

Macrobrachium ? species.
Nephrops costatus Rathbun.
species.
Axius ? species.
Hepatus chilensis Milne Edwards.

CRUSTACEA—continued.

Calappa flammea Rathbun.
Leucosilia jurinei (Saussure).
Leucosiidae, genus and species indeterminable.
Arenaeus species.
Panopeus antepurpureus Rathbun.
tridentatus Rathbun.
Uca macrodactylus (Milne Edwards and Lucas).
Parthenope pleistocenicus Rathbun.

CORRELATION OF THE SEDIMENTARY FORMATIONS OF PANAMA.

Tertiary Formations of the Southeastern United States.

A Table of the Tertiary geologic formations of the southeastern United States and their correlatives within that area, revised to the present date—October 15, 1917—is presented facing page 569. In 1912 I published a summary of the stratigraphy of the Tertiary formations of the Gulf and south Atlantic Coastal Plain, incorporating all data available up to that time,[1] and gave in the accompanying bibliography references to the principal literature. Since the summary referred to was printed a number of papers containing additional information have been published, and I have had the benefit of consulting the manuscripts of reports, to be mentioned later, not yet available in print. References to the later published and a few unpublished papers are as follows:

Berry, E. W., The physical conditions and age indicated by the flora of the Alum Bluff formation, U. S. Geol. Survey Prof. Paper 98, pp. 41–59, pls. 7–10, 1916.
——— The physical conditions indicated by the flora of the Calvert formation, Idem, pp. 61–73, pls. 11, 12, 1916.
——— The flora of the Citronelle formation, Idem, pp. 193–204, pls. 44–47, 1916.
——— The flora of the Catahoula sandstone, Idem, pp. 227–243, pls. 55–60, 1916.
——— The lower Eocene floras of southeastern North America, U. S. Geol. Survey Prof. Paper 91, pp. 481, 117 pls., 1916.
Brantly, J. E., A report on the limestones and marls of the Coastal Plain of Georgia, Georgia Geol. Survey Bull. 21, pp. 300, 11 pls., 1916.
Cooke, C. W., The age of the Ocala limestone, U. S. Geol. Survey Prof. Paper 95 (I), pp. 107–117, 1915.
——— The stratigraphic position and faunal associates of the orbitoid Foraminifera of the genus *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Paper 108 (G), pp. 109–113, 1917.
——— Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama, Washington Acad. Sci. Journ., vol. 8, pp. 186–198.
——— The Jackson formation and the Vicksburg group in Mississippi, Unpublished manuscript.
——— and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia, U. S. Geol. Survey Prof. Paper 120(E), pp. 41–81, pl. 7, figs. 7–9, 1918.
Cushman, J. A., Orbitoid Foraminifera of the genus *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Paper 108 (G), pp. 111–124 , pls. 43–44, 1917.
Dall, W. H., On a brackish water Pliocene fauna of the southern Coastal Plain, U. S. Nat. Mus. Proc., vol. 46, pp. 225–227, 1913.

[1] Vaughan, T.W., Earlier Tertiary (Eocene and Oligocene), Texas, Louisiana, and Arkansas, pp. 723–731; South Atlantic and eastern Gulf Coastal Plain and north end of Mississippi Embayment, pp. 731–745; Later Tertiary (Miocene and Pliocene), Texas, Louisiana, and Arkansas, pp. 804–806; South Atlantic and eastern Gulf Coastal Plain and north end of Mississippi Embayment, pp. 806–813: in Willis, Bailey: Index to the stratigraphy of North America, U. S. Geol. Survey Prof. Paper 71, 1912.

DALL, W. H., A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Florida, U. S. Nat. Mus. Bull. 90, pp. 173, 26 pls., 1915.
——— A contribution to the invertebrate fauna of the Oligocene beds of Flint River, Georgia, U. S. Nat Mus. Proc., vol. 51, pp. 487–524, pls. 83–88, 1916.
DEUSSEN, ALEXANDER, Geology and underground waters of the southeastern part of the Texas Coastal Plain, U. S. Geol. Survey Water-Supply Paper 335, pp. 365, 9 pls., 1914.
——— Geology of the Coastal Plain of Texas between Brazos and Nueces rivers, U. S. Geol. Survey Prof. Paper —— (manuscript not published).
——— and DOLE, R. B., Ground water in La Salle and McMullen counties, Texas, U. S. Geol. Survey Water-Supply Paper 375 (G), pp. 141–177, pls. 9, 10, 1916.
DUMBLE, E. T., Some events in the history of the present Coastal area of the Gulf of Mexico in Texas and Mexico, Journ. Geol., vol. 23, pp. 481–498, 1915.
——— Problems of the Texas Tertiary sands, Geol. Soc. America Bull., vol. 26, No. 4, pp. 447–476, pls. 25–27, 1915.
——— Tertiary deposits of northeastern Mexico, California Acad. Sci. Proc., ser. 4, vol. 5, pp. 163–193, pls. 16–19, 1915.
LOWE, E. N., Preliminary report on iron ores of Mississippi, Miss. Geol. Survey Bull. 10, pp. 70, 7 pls., 1913. See especially pp. 23–25.
——— Mississippi, its geology, geography, soils, and mineral resources, Idem, Bull. 12, pp. 335, 28 pls., 1 geol. map, 1915.
MANSFIELD, W. C., Mollusks from the type locality of the Choctawhatchee marl, U. S. Nat. Mus. Proc., vol. 51, pp. 599–607, pl. 113, 1916.
MATSON, G. C., The phosphate deposits of Florida, U. S. Geol. Survey Bull. 604, pp. 101, 17 pls., 1915.
——— The Pliocene Citronelle formation of the Gulf Coastal Plain, U. S. Geol. Survey Prof. Paper 98, pp. 167–192, pls. 32–43, 1916.
——— The Catahoula sandstone, Idem, pp. 209–226, pls. 48–54, 1916.
———, and SANFORD, S., Geology and groundwaters of Florida, U. S. Geol Survey Water-Supply Paper 319, pp. 445, 17 pls., 1913.
ROGERS, G. S., The phosphate deposits of South Carolina, U. S. Geol. Survey Bull. 580 (J), pp. 183–220, pl. 2, 1914.
SELLARDS, E. H., Fossil vertebrates from Florida: A new Miocene fauna, Florida Geol. Survey Eighth Ann. Rept., pp. 83–93, 1916.
SHAW, E. W., Pliocene of northeastern Mississippi, U. S. Geol. Survey Prof. Paper 108 (H), pp. 125–163, pls. 45–60, figs. 21–25, 1918.
SHEARER, H. K., A report on the bauxite and fuller's earth of the Coastal Plain of Georgia, Georgia Geol. Survey Bull. 31, pp. 340, pls. 16, 1917.
STEPHENSON, L. W., and VEATCH, J. O., Underground waters of the Coastal Plain of Georgia, U. S. Geol. Survey Water-Supply Paper 341, pp. 539, 21 pls., 1915.
——— ———, and CRIDER, A. F., Geology and groundwaters of northeastern Arkansas, U. S. Geol. Survey Water-Supply Paper 399, pp. 315, 11 pls., 1916.
VAUGHAN, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, California, and its significance, U. S. Geol. Survey Prof. Paper 98 (T), pp. 355–386, pls. 92–102, 1917.
——— Correlation of the Tertiary formations of the southeastern United States, Central America, and the West Indies, Washington Acad. Sci. Journ., vol. 8, pp. 268–276, 1918.
——— and COOKE, C. W., Correlation of the Hawthorn formation, Washington Acad. Sci. Journ., vol. 4, pp. 250–253, 1914.

In the bibliography, except the one by Professor Berry on the flora of the Calvert formation, I have purposely omitted references to papers on that part of the Coastal Plain north of the South Carolina-North Carolina boundary line. The contributions to the paleontology and stratigraphy of the Tertiary formations of the south Atlantic and Gulf Coastal Plain during the past five years have been considerable, as the list of papers shows, but much more work has been done. Prof. E. W. Berry has completed a monograph of the middle and upper Eocene floras of southeastern North America, now awaiting publication as a Professional Paper of the United States Geological Survey; Dr. Joseph A. Cushman has a monograph of the Pliocene and Miocene Foraminifera of the Coastal Plain in press as a bulletin of the United States Geological Survey; Messrs. F. Canu and R. S. Bassler have submitted the manuscript for a very large volume on

the Eocene and lower Oligocene Bryozoa of the Coastal Plain for publication by the United States National Museum; Miss Julia Gardner has completed the manuscript of a monograph on the Mollusca of the Chipola marl, Oak Grove sand, and Shoal River marl members of the Alum Bluff formation; and Dr. C. W. Cooke has completed the field work of a geologic reconnaissance of the Coastal Plain of South Carolina, on a scale of 1:500,000. The results of all this unpublished work have been available to me, and I have utilized them in preparing the correlation table.

The only specific correlations that it seems desirable to discuss in this connection are those of the upper Eocene of Texas. Dumble, in his papers already cited, represents upper Claibornian deposits as being absent in Texas, referring his Fayette and Yegua formations to the lower Claiborne, while the Frio is placed doubtfully in the same division of the Claiborne. The Fayette overlies the Yegua, which is the same as the formation to which I applied the name "Cocksfield Ferry beds" in 1895.[1] In my papers cited below[1] I made it perfectly clear that that formation overlies the lower Claiborne deposits, to which Harris later applied the name St. Maurice formation, and underlies the marine fossiliferous Jackson as exposed on Red River at Montgomery, Louisiana, and that it must include the deposits in Louisiana that are the stratigraphic equivalent of the upper Claiborne, subsequently designated Gosport sand, of Alabama. There was no escape from this correlation at the time I made it, and it has subsequently been repeatedly corroborated by others. Although the basal part of the Yegua is probably the equivalent of the upper part of the lower Claiborne Lisbon formation, the greater part of the Yegua is of upper Claiborne age, and it is the Texas correlative of the Gosport sand of Alabama. Berry's unpublished studies of the middle and upper Eocene floras of southeastern North America supply further corroboration of this correlation, and he authorizes me to say that some of the upper beds of the Yegua may be of lower Jackson age.

So long ago as 1902 Miss Maury published the following statement regarding the Fayette sandstone: [2]

> In 1895 Mr. William Kennedy [3] referred both the Fayette sandstone and the Frio, clays to the lower Claiborne because of the presence of *Venericardia planicosta* in the sandstones. Mr. Veatch, during the winter of 1902, has examined the sandstones and finds *Venericardia planicosta* is limited to the basal layers of the formation. These he refers to the Jackson.

[1] Vaughan, T. W., Stratigraphy of northwestern Louisiana, Amer. Geologist, vol. 15, pp. 205–229, pl. 9, 1895; A brief contribution to the geology and paleontology of northwestern Louisiana, U. S. Geol. Survey Bull. 142, pp. 65, 4 pls., 1896.

[2] Maury, Carlotta J., A comparison of the Oligocene of western Europe and the southern United States, Bull. Amer. Paleontology, vol. 3, p. 80, 1902.

[3] Kennedy, William, Eocene Tertiary of Texas, Acad. Nat. Sci. Philadelphia Proc. for 1895, pp. 92, 98, 1895.

I have visited, in company with Mr. Alexander Deussen, the fossiliferous exposures near Wellborn, Texas. I collected fossils and have studied them. I concur with Mr. Veatch in his opinion that they are of Jackson age. Mr. Deussen has traced the formation westward; it is persistent and persistently overlies the Yegua formation at least for some miles beyond Nueces River.[1] The Frio clay overlies the Fayette sandstone, and it contains *Ostrea georgiana*, a species that is abundant in the Jackson formation in Alabama and in the Barnwell formation, which is the correlative of the Jackson formation, in eastern Georgia. The Fayette sandstone and the Frio clay of Texas are the correlatives of the Jackson formation of Louisiana and Mississippi. The following table shows the stratigraphic equivalence:

Correlation of the middle and upper Eocene of Texas.

	Mississippi.	Louisiana.	Texas (east of Nueces River).
Claiborne group	Jackson formation	Jackson formation	Frio clay. Fayette sandstone.
	Yegua formation Lisbon formation Tallahatta buhrstone	Yegua formation St. Maurice formation	Yegua formation. Cook Mountain formation. Mount Selman formation.

Southward and westward of a line, the location of which is indicated on Deussen's map,[1] there is a change in the strike of the formations. The line passes between Cotulla and Tilden and strikes from about N. 52° W. to S. 52° E.; northeast of it, the strike of the formations is S. 39° W., with a southeastward dip of 48 feet to 1 mile; southwest of it, the strike is N. 19° E., with a dip S. 19° E. of 36 feet to 1 mile. In 1912 Mr. G. C. Matson devoted some months to a field study of the area along Rio Grande seaward of the Eocene-Cretaceous contact, and I accompanied him during a wagon trip from Laredo to Samfordyce. As Mr. Matson has not been able to prepare a report for publication, it is fortunate that I made notes on the exposures we examined, and later the marine fossils collected were studied and identified by Dr. C. W. Cooke and myself. Through out much of its course between Laredo and Roma, Rio Grande is a subsequent stream—that is, its course is along the strike of the formations—and for miles the road is on very nearly the same geologic formation. However, only a short distance eastward from the river higher geologic formations are encountered. The most important difference of the successive formations, as compared with those farther east, consists in the slight development of the lignitiferous Yegua formation, which, apparently, is represented by shoal-water marine sands. The correlative of the Fayette sandstone was not

[1] U. S. Geol. Survey Water-Supply Paper 375, pl. 8, 1916.

A PROVISIONAL CORRELATION TABLE OF THE TERTIARY FORMATIONS OF THE SOUTH ATLANTIC AND EASTERN GULF COASTAL PLAIN OF THE UNITED STATES.

Age of deposits.		North Carolina (south of Hatteras axis).	South Carolina (Santee drainage).	South Carolina and Georgia (Savannah drainage).	Georgia (Chattahoochee drainage).	Florida.		Alabama.		Mississippi.		Louisiana.
Pliocene.		Waccamaw marl.	Waccamaw marl.	Not recognized.		Caloosahatchee marl, Nashua marl, Alachua clay, and Bone Valley gravel (largely contemporaneous).	Citronelle formation.	Citronelle formation.		Citronelle formation.		Citronelle formation.
Miocene.	Upper.	Duplin marl.	Duplin marl.	Duplin marl.		Jacksonville formation.	Choctawhatchee marl.	Pascagoula clay.		Pascagoula clay.		Pascagoula clay.
		Unconformity	Unconformity	Unconformity								
			Edisto marl.									
				Marks Head marl.								
	Middle.											
				Unconformity		Unconformity						
	Lower.			Alum Bluff formation.	Alum Bluff formation.	Alum Bluff formation.	Shoal River marl member.	Alum Bluff formation.	Hattiesburg clay.	Hattiesburg clay.		Hattiesburg clay.
							Oak Grove sand member.					
							Chipola marl member.					
Oligocene.	Upper.			Chattahoochee formation.	Chattahoochee formation.	Tampa formation.	Chattahoochee formation.	Chattahoochee formation.	Catahoula sandstone.	Catahoula sandstone.		Catahoula sandstone.
	Middle.				Unconformity							
	Lower.				Vicksburg formation.	Vicksburg group.	Marianna limestone (western Florida).	Vicksburg group.	Marianna limestone (with Glendon limestone member).	Vicksburg group.	Byram calc. marl.	Vicksburg limestone.
											Marianna limestone (with Glendon limestone and Mint Spring calc. marl members).	
									Red Bluff clay.		Red Bluff clay.	
Eocene.	Upper.	Castle Hayne limestone. Trent marl.	Cooper marl. Barnwell formation.	Barnwell formation (with Twiggs clay member).	Ocala limestone.	Ocala limestone.		Ocala limestone.	Jackson formation.	Jackson formation (with Yazoo clay member and Moodys calc. marl member).		Jackson formation.
	Middle.		McBean formation.	McBean formation.	McBean formation.	(Buried.)		Claiborne group.	Gosport sand.	Claiborne group.	Yegua formation.	Claiborne group. Yegua formation.
									Lisbon formation.		Lisbon formation.	St. Maurice formation.
									Tallahatta buhrstone.		Tallahatta buhrstone.	
	Lower.		Congaree shales of Sloan.	(Probably overlapped.)	Wilcox formation.	(Buried.)		Wilcox group.	Hatchetigbee formation. Bashi formation. Tuscahoma formation. Nanafalia formation.	Wilcox group.	Granada formation. Holly Springs sand. Ackerman formation.	Wilcox formation.
			Williamsburg formation.									
			Black Mingo formation.	(Probably overlapped.)	Midway formation.	(Buried.)		Midway group.	Naheola formation. Sucarnochee clay.	Midway group.	Tippah sandstone of Lowe. Porters Creek clay.	Midway formation.
									Clayton limestone.		Clayton limestone absent or replaced by sand.	

definitely recognized, but Professor Berry has identified a Jacksonian flora, collected by Mr. Matson, "4½ miles north of Miraflores Ranch, 45 miles southeast of Laredo," and says in a letter: "I consider the Miraflores Ranch outcrops as Fayette sandstone and of lower Jackson age. I am sure that it is not upper Claiborne; in fact, I believe that a part of the Yegua in the Texas area is also lower Jackson in age."

The Frio clay is represented by clays that contain abundant specimens of *Ostrea georgiana*. The importance of these notes in this connection consists in showing that marine deposits of Jackson age extend to Rio Grande, but the strike veers southward in conformity with the trends of the shore of the Gulf of Mexico and of the mountains in eastern Mexico.

Correlation of the Tertiary Formations of the Southeastern United States with European Subdivisions of the Tertiary.

EOCENE.

As the remarks to be made here are intended to be only a summary, no extensive account of literature will be given. However, it should be mentioned that Dr. W. H. Dall's correlation table, published nearly 20 years ago,[1] is valuable in that it gave a summary of opinion up to 1898 and served as a starting point for subsequent attempts of a similar kind. A comparison of the correlation table of the formations in the southeastern United States here presented with Doctor Dall's shows that during the past 20 years many modifications or changes in opinion have been rendered necessary because of the acquirement of new information.

The most recent discussion of the European equivalence of the lower Tertiary deposits of the Coastal Plain is that of Berry, who in his lower Eocene floras[2] presents the following table of the names applied to the European "stages":

Lower Eocene	Ypresian (Dumont, 1849)	Marine facies=Cuisian. Lagoon facies=Laonnian.
	Sparnacian (Dollfus, 1880)=Upper Landenian (Mayer Eymar, 1857).	
Basal Eocene.	Thanetian (Renevier, 1873)=Heersian (Dumont, 1849), Lower Landenian (Mayer Eymar, 1857).	
	Montian (Dewalque, 1869)=Paleocene of Von Koenen and others. (Not of Schimper, 1874.)	

Berry says: "Together these stages correspond to the Eonummulitic of Haug (1911), to the Suessonian of D'Orbigny, and to the Paleocene of Schimper (1874), but not to the Paleocene of Von Koenen, Dollo, and others, which is limited to the Montian stage."

[1] Dall, W. H., A table of the North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 323–348, 1898.

[2] U. S. Geol. Survey Prof. Paper 91, pp. 140–152.

With regard to the age of the Midway flora, he says:[1] "The European floras most similar to that of the Midway (?) are those, likewise poorly represented in marine deposits, of the Montian and Thanetian stages in the so-called Paris Basin in northern France, Belgium, and southeastern England."

He concludes his discussion of the correlation of the Wilcox floras with the following statement:[2] "In view of the foregoing discussion, I have no hesitation in making the most positive statement that the Wilcox flora is largely of Ypresian age. This is rendered conclusive by the exact agreement between the flora of the overlying Claiborne group and that of the Lutetian of Europe, as brought out in my unpublished studies of the Claiborne flora."

The foregoing paragraph contains Berry's opinion in 1916 as to the equivalence of the Claiborne group of the southern United States with the Lutetian of western Europe. This is an old correlation, for it is the same as that made by De Lapparent.[3] More recent studies, not yet published, have led Berry to correlate the Claiborne flora of the southeastern United States with the Auversian of Europe, and he grants me permission to present his conclusion in this connection.

As a part of my discussion of the coral faunas of the Jackson formation and its correlatives, page 198 of this volume, I have expressed my opinion that the Jacksonian of Mississippi and Albama is the equivalent of the Bartonian-Ludian of western Europe, thereby concurring in a previously expressed opinion of Haug, which is essentially the same as that of De Lapparent.[4] In fact, this opinion seems generally accepted by all geologists who have studied the subject.

OLIGOCENE.

That the Vicksburgian Oligocene is the equivalent of the European Tongrian[5]-Sannoisian-Lattorfian has long been recognized and needs only mention in this place.

As a part of the discussion of the coral faunas, pages 199–207 of this volume, I have correlated the basal part of the Chattahoochee formation with the Rupelian-Stampian of western Europe. This conclusion, which seems to me firmly established, is new for the marine Tertiary formations of continental North America.

That the Tampa formation of Florida is the equivalent of the European Aquitanian, which seems to include the Chattian, is generally acknowledged. This is the opinion of W. H. Dall and M. Cossmann,

[1] U. S. Geol. Survey, Prof. Paper 91, p. 11.

[2] Idem. p. 152.

[3] De Lapparent, A., Traité de géologie, p. 1454, 1900.

[4] Traité de géologie, ed. 4, p. 1473.

[5] Maury, Carlotta J., A comparison of the Oligocene of western Europe and the southern United States, Bull. Amer. Paleontology, vol. 3, No. 15, pp. 313–404, pls. 20–29, 1902. Here it should be noted that Tongrian has been used in two senses, one as the equivalent of the lower (Lattorfian) and the other as the equivalent of the middle (Rupelian) Oligocene. Miss Maury used it in the former sense.

and apparently Mr. R. B. Newton agrees with them.[1] The papers cited below contain the opinions referred to, and additiomal references to literature are given in the footnotes to Doctor Dall's paper. On page 211 of this volume, under my discussion of the successive American coral faunas of Tertiary age, the same opinion is expressed. Paleontologists are divided in opinion as to whether the Aquitanian should be referred to the Oligocene or to the Miocene.

From my experience with American faunas I incline to consider it as belonging to the older series. The Rupelian (basal Chattahoochee and Antiguan) fauna has much in common with the Sannoisian-Lattorfian (Vicksburgian) faunas, on the one hand, and with the Aquitanian (Tampa) fauna on the other. The failure to discover *Lepidocyclina* at Tampa seems to me of no great value as evidence, for, so far as I am aware, no careful search for Foraminifera has been made in the "silex" bed. Should the specimens not have been destroyed by changes in the sediments subsequent to deposition, it is my expectation that either *Lepidocyclina* or *Heterosteginoides*, or both, will be found at Tampa, for in the Canal Zone both of those genera of Foraminifera are found in association with a fauna that I am correlating with the Tampa, and *Heterosteginoides* occurs in Anguilla. Mr. Newton, in his note cited, states that "Nummulites died out at the end of Oligocene time, being replaced by Lepidocycline Foraminifera in the succeeding Aquitanian and later stages of the Miocene period." This is an unfortunate remark, for the type-species of *Lepidocyclina* is *L. mantelli* (Morton) from the Vicksburgian Oligocene of the Gulf States. It is now known that in Georgia the genus ranges stratigraphically as low in the Eocene as a middle Jacksonian horizon, overlapping the upward range of *Orthophragmina*,[2] and it is probable that it ranges as low as the base of the Jackson formation in Mississippi and Louisiana. *Nummulites panamensis* in the Canal Zone occurs at a horizon very nearly the same as that of the "silex" bed at Tampa. There are important differences between the Tampa and the later fauna of the Chipola marl, which is considered by the students of Florida stratigraphy, except Doctor Dall, as the basal member of the Alum Bluff formation. However, it should be recognized that the presence of the Chipola marl considerably west of the type locality on Chipola River indicates a persistence that may warrant according it formational rank. I am definitely placing the Chipola marl and the higher members of the Alum Bluff formation in the Miocene.

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[1] Dall, W. H., Note on the Oligocene of Tampa, Fla., the Panama Canal Zone, and the Antillean region, Malacolog. Soc. Proc., vol. 12, pp. 38, 39, 1916.
Newton, R. B., Remarks on Dr. Dall's paper, idem, p. 40.

[2] Generic determinations by Dr. Joseph A. Cushman.

MIOCENE.

ALUM BLUFF FORMATION.

In the foregoing paragraph and on pages 219–220, as a part of the discussion of the fossil coral-faunas, I have referred the Chipola marl member of the Alum Bluff formation to the basal part of the Miocene—that is, I correlate it with the base of the Burdigalian of European nomenclature. Unfortunately, information on the basal contact of the Chipola is not adequate. According to the description by Matson and Clapp [1] it conformably overlies the Chattahoochee formation. In 1900 I examined the exposure at the type locality, the McClelland farm on the west side of Chipola River, just south of Tenmile Creek, Calhoun County, Florida, and corroborated the previous observations of Dall and Stanley-Brown that the marl immediately overlies limestone at the top of the Chattahoochee formation, but did not study the nature of the contact in sufficient detail. Although the evidence is not definite, it is probable that the contact is one of erosion unconformity.

As regards the Mollusca of the Chipola marl, Miss Julia Gardner, who has almost completed a monographic account of them, furnishes me the following statement: "The earlier investigation of the Chipola fauna indicated that 'about 50 per cent of the species in the Chipola beds are peculiar to them; of the others the larger proportion are common to the Tampa *Orthaulax* bed while in the subsequent Oak Grove sands about 24 per cent of the Chipola species survive.' [2]

"Further investigations have, as is usually the case, materially increased the percentage of peculiar forms and materially diminished the percentage of species common to other horizons. The work upon the Chipola fauna is not yet complete but there is every reason to suppose that at least 75 per cent of the species are restricted to the single horizon. Twenty-three of the Tampa gastropods have been considered identical with those from the Chipola. In 18 out of the 23 the resemblances between the Tampa and Chipola forms are too slight to justify their inclusion under the same specific name. Two other species must be discarded for the present, because it has been impossible to find the Tampa individuals referred to them. Only 3 of the 23 remain; *Strombus chipolanus* is represented in the Tampa beds by material too imperfect to determine with complete assurance; *Xenophora conchyliophora* is a species which has persisted with no perceptible change of character from the Upper Cretaceous to the Recent; *Tegula exoleta* apparently initiated in the Tampa persisted throughout the Miocene. The relation between the

[1] Matson, G. C., and Clapp, F. G., A preliminary report on the geology of Florida, with special reference to the stratigraphy, Florida Geol. Survey 2d Ann. Rept., pp. 102, 103, 1910.

[2] Dall, W. H., A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Fla., U. S. Nat. Mus. Bull. 90, p. 8, 1915.

Tampa and Chipola pelecypods promises to be similar to that between the gastropods. No identical species of any significance has been found, and except a single conspicuous element the entire aspect of the fauna looks forward to the later Tertiary and Recent rather than backward. The presence of *Orthaulax*, that bizarre group so closely associated with the Oligocene of the southeast coast and the Antilles, is the one strong band between the Chipola and the later Oligocene faunas. This archaic type survived the break at the close of the Tampa and continued in considerable abundance throughout the Chipola, but no trace of it has been found in the later formations.

"The affinity between the Oak Grove and Chipola is much closer than the percentage of identical species indicates. Only about 15 per cent of the Chipola forms are common to the Oak Grove, although about 35 per cent of the Oak Grove forms are common to the Chipola. The Chipola fauna is remarkably varied and includes two decidedly distinct facies and a third more obscurely differentiated assemblage. The Oak Grove fauna, on the other hand, is much more uniform; it includes fewer species and has a much larger relative number of individuals. The facies of the Chipola fauna at the type exposure on Chipola River is much more closely allied to the Oak Grove than is the facies developed in the lower bed at Alum Bluff, which contains a rather prominent brackish water element. The third assemblage, a marine fauna known only from Boynton Landing on Choctawhatchee River, has a rather large number of peculiar species. Except *Orthaulax*, the prominent genera of the Chipola fauna on the Chipola River and those of the Oak Grove fauna are the same, and a goodly percentage, probably the majority, of the prolific species of the Oak Grove have closely related analogues in the Chipola fauna as represented on Chipola River. The change following the Chipola was apparently sufficient to exterminate the archaic types, together with a large number of the newer forms. The hardier types, however, survived and were apparently able to flourish with increased abundance in the less densely populated waters of the Oak Grove."

The Mollusca of this horizon are only remotely related to those of the Tampa formation, which is the stratigraphic equivalent of the upper part of the Chattahoochee formation, while they are closely related to those of the next higher zone, the Oak Grove sand. Because of the faunal kinship and the stratigraphic intergradation of the marl with the typical material of the Alum Bluff formation at Alum Bluff, it is classified with the Oak Grove sand as a member of the Alum Bluff formation.

Berry has described the small flora obtained in the Alum Bluff formation [1] in a paper by him already cited. The fossil plants at

[1] U. S. Geol. Survey Prof. Paper 98 (E), pp. 41–59, pls. 7–10, 1916.

Alum Bluff occur between 12 and 17 feet above the top of the Chipola marl. He says regarding this flora: "It is thus apparent that the Alum Bluff flora can be considered either Aquitanian or Burdigalian, with a slight preponderance of the evidence in favor of the Aquitanian, * * * If the Alum Bluff formation is of Aquitanian or Burdigalian age—and one or the other alternative seems certain—the more or less academic question is raised whether it shall be classed as Oligocene or Miocene."

The floral evidence at least does not contradict considering the Alum Bluff as Burdigalian.

The matrix of the Chipola marl is particularly suited for the preservation of Foraminifera, and they are very abundant; but there are no orbitoid Foraminifera, neither *Lepidocyclina* nor *Heterosteginoides*.

The Bryozoa of the Alum Bluff formation, according to Messrs. Canu and Bassler, are of distinctly Burdigalian affinities. The fauna is particularly characterized by the introduction of certain species that persist until the present time. Two of these species are *Cupularia umbellata* Defrance and *C. canariensis* Busk, both of which occur in the Chipola marl at its type locality, and both were collected by Doctor MacDonald on Banana River, Costa Rica, in deposits correlated with the Gatun formation, and both occur in the Bowden marl of Jamaica.

The evidence of the fossil corals and of the fossil vertebrates has been discussed on pages 219, 220 of this volume.

MARKS HEAD MARL AND CALVERT FORMATION.

The Marks Head marl at Porters Landing, Savannah River, Effingham County, Georgia, has been correlated by me with the Calvert formation of Maryland and Virginia.[1] The most recent discussion of the age equivalence of the Calvert with European horizons is that of Berry in a paper already mentioned.[2] He says, regarding the probable age of the formation: "Seven of the Calvert plants, or 26.9 per cent, are common to the Tortonian of Europe, and ten others, or 38 per cent, are represented in the Tortonian by very similar forms. In view of the fact that these floras spread into both regions from a common and equally accessible source, the evidence that the Calvert flora indicates a Tortonian age is as conclusive as intercontinental correlations ever can be."

According to this correlation of Berry, there is no Helvetian in the Atlantic and Gulf Coastal Plain of the United States.

[1] Vaughan, T. W., The Miocene horizons at Porters Landing, Georgia, Science, new ser., vol. 31, pp. 833, 834, 1910; and in Veatch, O., and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia, Georgia Geol. Survey Bull. 26, pp. 362–369, 1911.

[2] U. S. Geol. Survey Prof. Paper 98 (F), pp. 61–73, pls. 11, 12, 1916.

CHOPTANK AND ST. MARYS FORMATIONS.

Miss Julia Gardner contributes the following statement on these formations: "Because of faunal similarity with the Calvert formation, both the Choptank and the St. Marys formations are also correlated with the Tortonian of Europe, though, of course, they represent horizons slightly higher than that of the Calvert. The Choptank fauna is little more than a sandy bottom facies of the Calvert and is the biologic expression of the physical conditions attending its close. About 60 per cent of the Choptank species are present in the underlying formation, while approximately 30 per cent persist into the overlying St. Marys.

"The St. Marys fauna, though similar to those of the lower formations of the Chesapeake group in the general make-up, is differentiated from them by an influx of new forms and by the absence of those species peculiar to the cooler waters of the Calvert and the sands of the Choptank. The more modern element includes not far from 35 per cent of the entire St. Marys fauna."

YORKTOWN FORMATION AND DUPLIN MARL.

Miss Gardner has kindly prepared the following statement: "The change in the paleontologic character at the close of the St. Marys is much more significant than that preceding it. Although the percentage of new forms in the Yorktown is not remarkably large, the general facies shows a distinct advance over the St. Marys. The more primitive types, such as *Ostrea compressirostra*, had become extinct or they show an abrupt decrease in prominence, while a number of more advanced types such as *Arca lienosa*, which constitute conspicuous elements in the later faunas, are initiated at this horizon.

"The views advanced by Dall [1] on the approximate synchroneity of the Yorktown and Duplin faunas have been verified by subsequent investigations. Doctor Dall, in his discussion of Tertiary conditions along the East Coast, suggested the elimination of the cool inshore current of the earlier Miocene and the reestablishment of a Tertiary Gulf Stream as the probable cause of the subtropical aspect of the Duplin fauna. This late Miocene warm current apparently hugged the North Carolina shore even more closely than does the present Gulf Stream, but swung off into the open sea in the vicinity of Hatteras so that its influence upon the Yorktown fauna was almost negligible. The sea floor, on which the Dulphin marl, as at present known, was deposited, was apparently more sandy than that on which the St. Marys and Yorktown formations were laid down, as the conspicuous abundance in Virginia and northern North Carolina of such a form as *Mulinia congesta* indicates dominantly muddy bottom in some

[1] Dall, W. H., Contribntions to the Tertiary fauna of Florida, Wagner Free Inst. Sci. Phila. Trans. vol. 3, pt. 6, p. 1598, 1903.

portions at least of the area covered by deposits belonging to the Chesapeake group, while the profusion of *Oliva literata* and *Olivella mutica* give evidence of extensive sand flats in the area covered by the Duplin marl. Already in the late Tertiary, present day conditions had been approximated along the East Coast. The faunas of Virginia and North Carolina flourished in rather shallow inshore waters into which mud and sand were being freely carried, the waters of the Yorktown basin being slightly but not much warmer than those off the Virginia coast today; while the Duplin fauna was apparently in more direct communication with the Floridian life than are the present faunas off Hatteras and Cape Fear and indicate slightly warmer climatic conditions than do those of the Yorktown."

The Yorktown formation and the Duplin marl are the correlatives of the European stage next younger than the Tortonian, which would be the Sarmatian or Pontian or both.

CHOCTAWHATCHEE MARL.

The study that I made of the Mollusca from the Duplin marl as exposed at Porters Landing, Savannah River, Georgia,[1] and of Mollusca from exposures of the same formation in South Carolina, led me to the conclusion that the Choctawhatchee marl of Florida, exposed between Ocklocknee River, on the east, and Choctawhatchee Bay, on the west, is of very nearly the same, if not of the identical, age as the Duplin marl. Therefore, the Choctawhatchee marl and its correlative, the Jacksonville formation of east Florida, are about the same in age as the Sarmatian and Pontian of Europe.

The brackish water Pascagoula clay of the coastal area in Mississippi and Louisiana is probably of about the same age—that is, late Miocene.

PLIOCENE.

In the South Atlantic and Coastal Plain of the United States four formations, the Waccamaw marl of the Carolinas, the Nashua and Caloosahatchee marls of Florida, and the Citronelle formation of the Gulf States are definitely considered of Pliocene age. References to literature are not necessary, as they are given in the papers mentioned in the footnotes on pages 565, 566. At present correlation of these formations with the three recognized European stages, Plasancian, Astian, and Sicilian is not warranted. According to Berry, the flora of "the Citronelle formation belongs in the later half of the Pliocene epoch and is directly ancestral to the Pleistocene and Recent floras of the same region."

[1] Georgia Geol. Survey Bull. 26, pp. 367–369, 1911.

Age of the Sedimentary Formations of Panama, and the Distribution of their Age-Equivalents in Central America and the West Indies.

EOCENE.

The oldest deposit from which Eocene fossils were obtained is a dark-gray argillaceous sandstone near Tonosi. Here specimens of *Venericardia planicosta* closely resembling a variety found at Claiborne, Alabama, were collected. The evidence of one species is meager, but as much as there is points to the deposit being of Claibornian-Lutetian (or Auversian) age.

Deposits of Claibornian age extend as a belt from South Carolina across Georgia into Alabama, thence through Mississippi, eastern Arkansas, Louisiana, and Texas, and into Mexico.[1]

Although deposits of upper Eocene (Jacksonian) age have not been positively identified in Panama, they probably are there. Doctor Cushman inclines to the opinion that the limestone containing *Orthophragmina minima* at David is of upper Eocene age. Upper Eocene deposits occur in Nicaragua, St. Bartholomew, Jamaica, Cuba, in the southeastern and southern United States from North Carolina to Mexico, and probably in northern Colombia. The correlation and distribution of deposits of this age are discussed on pages 193–198 in the account of the fossil coral-faunas. They are the American representatives of the European Bartonian-Ludian-Priabonian stage.

It is highly probable that upper Eocene marine sediments are present on the island of Antigua. Hussakoff has described[2] a fossil fish, *Zebrasoma deani*, from a quarry belonging to Mr. Oliver Nugent. I did not visit this quarry but saw it from a distance. It is at a place known as Golden Grove, which is 1.4 nautical miles nearly due south from the Cathedral in St. John, about 400 feet east of the southern end of a north and south line, and is in a sandstone or bedded tuff that is stratigraphically below the middle Oligocene Antigua formation. I believe Hussakoff is correct in assigning a probably Eocene age to the fossil.

Although it is probable that deposits of upper Eocene age occur in a number of other West Indian islands, Haiti, Porto Rico, the Virgin Islands, St. Croix, Guadaloupe, Martinique, and Barbados, the available evidence is indecisive. Gregory[3] expressed the opinion in 1895 that the Scotland "beds" of Barbados are of lower Oligocene age.

According to Douvillé, in his latest paper[4] on the orbitoids of Trinidad, there are in that island deposits of Lutetian, Auversian, and

[1] See p. 565 of this volume.

[2] Hussakoff, L., *Zebrasoma deani*, a fossil surgeon fish from the West Indies, Amer. Mus. Nat. Hist. Bull., vol. 23, pp. 125, 126, pl. 7, 1907.

[3] Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, p. 298, 1895.

[4] Comptes Rend., vol. 164, pp. 841–847, 1917.

Priabonian age. Miss Maury[1] correlates the basal bed of the exposure at Soldado Rock, Trinidad, with the Midway group of the Gulf Coastal Plain of the United States, but I am not convinced that the fauna is quite so old. In fact, the paleontologic evidence seems to me just about as strongly in favor of the horizon corresponding to one in the Wilcox group. Douvillé is of the opinion that most of Miss Maury's horizons are younger than the age she has assigned them. There are discrepancies between Miss Maury's and Douvillé's correlations that probably can be reconciled only by a critical study of Foraminifera positively known to be associated with the respective beds in which the Mollusca were collected. I have had considerable experience in checking M. Douvillé's results, and, except that he does not understand all of the stratigraphic nomenclature and is greatly confused as to some of the stratigraphic relations in the southeastern United States, I have usually found his deductions as to the age of formations valid. It seems to me that the table in his last paper on the Trinidad orbitoids is correct, except that it seems to me more appropriate to refer the Aquitanian to the Oligocene than to the Miocene.

OLIGOCENE.

LOWER OLIGOCENE.

The quotation, page 549, from Douvillé indicates the presence on the Haut Chagres of limestone of lower Oligocene (Lattorfian) age, as it contains specimens of *Orbophragmina* (*Asterodiscus*) species in association with *Lepidocyclina* species resembling *L. chaperi.*

Doctor MacDonald collected in the river bed at David, station 6512, *Lepidocyclina macdonaldi, L. duplicata, L. panamensis, Orbophragmina minima,* and *Nummulites davidensis;* at station 6526, in limestone which according to his section immediately underlies the limestone at station 6512, where he obtained *Lepidocyclina* species undetermined and *Nummulites davidensis;* and he found at station 6523, 2 miles north of David, *Lepidocyclina macdonaldi* and *L. duplicata.* These three localities represent very nearly, if not precisely, the same horizon, and have faunal characters very similar to those of the horizon in Trinidad that Douvillé correlates with the "Stampien inférieur," which, according to him, is Lattorfian. It therefore seems that the limestone in and north of David is of lower Oligocene (Lattorfian) age, and is the correlative of the Vicksburg group of the eastern Gulf States of the United States. Doctor Cushman's opinions as to the probable Eocene age of this limestone was given on page 550.

It is probable that the Bohio conglomerate is of this age, for it contains the Oligocene plant, *Taenioxylon multiradiatum* Felix, which

[1] Maury, Carlotta J., A contribution to the paleontology of Trinidad, Acad. Nat. Sci. Philadelphia Journ., ser. 2, vol. 15, pp. 25–112, pls. 5–13, 1912.

also occurs in the Oligocene of Antigua, and according to Doctor MacDonald the Bohio underlies the Culebra formation, the lower part of which seems to be of middle Oligocene age. However, the Bohio may be of middle Oligocene instead of lower Oligocene age.

Romanes reports from Manzanilla, on the Pacific coast of Costa Rica,[1] a cherty rock in which there are remains of Foraminifera, including *Gobigerina* and "a complex form allied to *Tinoporus*," which according to Dr. R. L. Sherlock is "most probably a species of *Orbitoides*." As the so-called species of *Tinoporus* from Trinidad, according to Douvillé, are referable to *Orbophragmina* (*Asterodiscus*), it appears almost certain that the "form allied to *Tinoporus*" mentioned by Romanes is a species of *Asterodiscus*. Dr. J. A. Cushman has examined Romanes's figure, [2] based on a photomicrograph of a thin section of the rock from Manzanilla, and writes me that it shows "*Orbophragmina* and abundant *Globigerina*, and that the rock may be similar to that at David and on Haut Chagres." The evidence is not entirely decisive, but the probability is very strong that the rock from Manzanilla, Costa Rica, is of lower Oligocene (Lattorfian) age as is that at David and on Haut Chagres. It is unfortunate that the box containing Mr. Romanes's most important specimens was lost in transit, but, notwithstanding this loss, he has made a valuable addition to the literature on the geology of Costa Rica.

Hill, in his description of a geologic section from San Jose, Costa Rica, to the coast at Port Limon, says: "At Guallava, the next station east of Las Animas, the Tertairy rocks are of Vicksburg age, according to Dr. Dall."[3] On page 275 of Hill's paper, Doctor Dall lists from this locality "the genuine *Orbitoides mantelli, Phos, Dentalium, Plicatula, Anomia*, etc., all Vicksburg species."

Between Costa Rica and Mexico there is no definite evidence as to the presence or absence of lower Oligocene deposits, but as Sapper mentions *Nummulites* from Zacualpa, Yucatan, either Eocene or Oligocene occurs at this place;[4] and, judging from the indefinite statements of Sapper, deposits of either Eocene or Oligocene age underlie extensive areas in Chiapas and northern Guatemala.[5]

Felix and Lenk [6] report *Nummulites* and "*Orbitoides*" in northern Chiapas, from collections made by Karsten, and refer them to the Eocene, but sufficient data are not given to decide whether the

[1] Romanes, J., Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 130, 131, pl. 9, fig. 4, 1912.

[2] Idem., pl. 9, fig. 4.

[3] Hill, R. T., The geologic history of the Isthmus of Panama and portions of Costa Rica, Mus. Comp. Zool. Bull., vol. 28, No. 5, p. 232, 1898.

[4] Sapper, Carlos, La geographia fisica y la geologica de la Peninsula de Yucatan, Mexico Inst. geol. Bol. 3, p. 7, 1896.

[5] Petermann's Mittheil., Ergänzungs vol. 27, Ergänzungsheft. 127, p. 67, 1899.

[6] Felix, J., and Lenk, H., Ueber das Vorkommen von Nummulitenschichten in Mexico, Neues Jahrb. für Min. Jahrg. 1895, vol. 2, pp. 208–209, 1895.

deposits are of Eocene or Oligocene age. Aurelius Todd collected at Tumbala, Chiapas, station 6403 U.S.N.M. register, *Lepidocyclina* in quantity and a *Nummulites* possibly allied to a species described by Cushman from St. Bartholomuw. Cushman says, "I should say that the material represents a lower Oligocene horizon."

Lepidocyclina and other Foraminifera that appears to be nummulitic were obtained by P. C. Steward and C. W. Washburne 500 meters southeast of Pecero, 8 leagues southwest of Ozuluama, Vera Cruz, Mexico, station 5462 U.S.N.M. register. Doctor Cushman says that at best some of this material is from strata of Oligocene age, but he does not express an opinion as to what part of the Oligocene it represents.

Lower Oligocene deposits probably occur in eastern Mexico, north of the Tamaulipas Range, for Dumble reports a *Pecten* recalling *Pecten poulsoni* Morton, specimens identified by Doctor Dall.[1] South of that range, the same author records "*Orbitoides papyracea, Cristellaria,* and *Nummulites,* from the Buena Vista to the Tancochin at Cerro del Oro."[2] The paleontologic evidence is indecisive, for the "*Orbitoides papyracea*" is certainly misidentified; but the specimens probably represent a large species of *Lepidocyclina,* of the kind abundant in the lower Oligocene and upper Eocene of the southeastern United States and in the middle Oligocene of Antigua and Georgia. The deposits from which the Foraminifera were obtained may be of upper Eocene or of upper or middle Oligocene age, but the probability is that they are lower Oligocene in age.

No marine Oligocene deposits are known in the State of Texas. Berry reports *Palmoxylon texense* Stenzel, from 5 miles north of Jasper, Texas, from "beds of Vicksburg age,"[3] and states that "Unstudied material indicates the probable presence of this species at several localities in the Catahoula sandstone of Texas and in the Vicksburg limestone of Alabama." There is marine lower Oligocene in Louisiana at Rosefield, near Washita River; and east of Mississippi River it outcrops in a belt running from Vicksburg eastward to Georgia and Florida.

Marine deposits in Cuba have been questionably referred to the lower Oligocene, but a definite opinion must be withheld until Doctor Cushman has completed his study of the Cuban orbitoid Foraminifera.

The geologic formation in Jamaica to which Hill applied the name Montpelier white limestone[4] contains many Foraminifera,

[1] Dumble, E. T., Tertiary deposits of northeastern Mexico, California Acad. Sci. Proc., ser. 4, vol. 5, p. 188, 1915.

[2] Dumble, E. T., Some events in the Eocene history of the present coastal area of the Gulf of Mexico in Texas and Mexico, Journ. Geol., vol. 23, No. 6, p. 496, 1915.

[3] Berry, E. W., The flora of the Catahoula sandstone, U. S. Geol. Survey Prof. Paper 98 (M), pp. 235, 236, pl. 56, 1916.

[4] Hill, R. T., The geology and physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, pp. 137–144, 1899.

one of which was identified by Bagg as *Orbitoides mantelli*, and is definitely correlated by Hill with the Vicksburg deposits of Mississippi. The identification of *Orbitoides* (*Lepidocyclina*) *mantelli* is subject to doubt, and the doubt attaching thereto affects the validity of Hill's correlation. However, the fact that the Montpelier limestone overlies the upper Eocene Cambridge formation and that a stratigraphic break occurs between it and the Bowden marl is strong stratigraphic evidence in favor of the correctness of Hill's opinion. The stratigraphic evidence leads to the supposition that the orbitoidal Foraminifera belong to the genus *Lepidocyclina*, and their having been identified as *Orbitoides mantelli* indicates that they have the form of that species. From the available evidence I consider Hill's conclusion justified, but until the Foraminifera have been critically studied the correlation is only tentative.

Hill[1] presents a correlation of Tippenhauer's columnar section for the island of Haiti with the Jamaican formations. Tippenhauer gives very meager information on the paleontology of Haiti, but he does say that the yellow limestone, the formation overlying Eocene conglomerate, contains "*Orbitoides.*"[2] Gabb mentions the abundance of "*Orbitoides*" in Santo Domingo,[3] but his statements are indefinite. It will later be made clear (p. 591 of this volume) that orbitoid Foraminifera are absent in Santo Domingo in deposits of the same age as and younger than the Bowden marl. The orbitoidal limestones of Santo Domingo are therefore older than the Miocene of Rio Gurabo, etc., and are probably of lower or middle Oligocene age, although they may be of upper Oligocene age. Additional stratigraphic and paleontologic work is needed before reliable conclusions on these matters are possible.

There is at present no information that suggests the presence of lower Oligocene marine deposits in the West Indies east and south of Haiti. At the base of the Pepino formation in Porto Rico and of the Antigua formation in Antigua there are erosion unconformities, indicating periods of uplift during the lower Oligocene. I have not been able to procure information on Guadaloupe or Martinique that would serve as a basis for an opinion on the age of the lower formations in these islands.

On the island of Trinidad lower Oligocene (Sannoisian and lower Stampian of Douvillé)[4] is well developed.

There is no information on northern South America.

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[1] The geology and physical geography of Jamaica, p. 172.

[2] Tippenhauer, L. G., Die Insel Haiti, vol. 1, pp. 86, 87, 1892.

[3] Gabb, W. M., On the topography and geology of Santo Domingo, Amer. Philos. Soc. Trans., new ser., vol. 15, p. 96, 1873.

[4] Douvillé, H., Les Orbitoïdes de l'île de la Trinité, Comptes Rend., vol. 161, pp. 87-92, 1915; Les Orbitoïdes de l'île de la Trinité, Idem, vol. 164, pp. 841-847, 1917.

MIDDLE OLIGOCENE.

As stated on page 203 in the discussion of the coral faunas, the Antiguan Oligocene must, in my opinion, be taken as the type formation and type locality of the middle (Rupelian) Oligocene of America. I have definitely correlated with this horizon the reef-coral fauna from Tonosi, Panama, station 6587, which I consider to be the stratigraphic equivalent of the lower part of the Culebra formation. *Lepidocyclina panamensis* and *L. duplicata* are associated Foraminifera. The presence of marine deposits of this age in Antigua, Porto Rico, Santo Domingo, Cuba, Florida, Alabama, and eastern Mexico has been mentioned on pages 199–207.

Messrs. Roy E. Dickerson and W. S. W. Kew have recently published a paper[1] in which they say: "most of the localities listed below appear to belong to the San Fernando formation of Dumble." This name is invalid, because it is preoccupied by the name of certain formations in Trinidad, and has been renamed San Rafael formation by E. T. Dumble. On page 205 of this volume I correlate it with the middle Oligocene Antigua formation, the basal part of the Chattahoochee formation, and the European Rupelian, on the basis of the corals, which possess no such heterogeneous stratigraphic affinities as the fossils recorded by Messrs. Dickerson and Kew. I will not here undertake to analyze the fauna they report, but will say that it contains names of species of upper Eocene (Jackson-Ludian), lower Oligocene (Vicksburgian-Lattorfiam), upper Oligocene (upper Chattahoochee-Tampa-Aquitanian), and lower Miocene (lower part of the Alum Bluff and the higher horizon represented by the Bowden marl-Burdigalian) age. In fact their list includes nearly every horizon from upper Eocene almost to middle Miocene. I will not attempt to explain this surprising paleontologic assemblage as the collections may represent a number of horizons, the species may be misidentified, or some of the species may have extraordinary stratigraphic ranges; and it will be mentioned that, as in at least one instance Cotteau made an error in stating the locality at which the type of a species was collected, there is some confusion for which Messrs. Dickerson and Kew are not responsible. An attempt will be made to remove in the forthcoming memoirs on West Indian paleontology as much of this kind of confusion as is possible.

West of Alabama in Mississippi and Louisiana there are plant-bearing beds of middle Oligocene age, for a considerable part of the Catahoula sandstone is certainly of that age, but that formation seems to include beds of lower, middle, and probably upper Oligocene age. No middle Oligocene deposits are known in Texas. There is no

[1] The fauna of a medial Tertiary formation and the associated horizons of northeastern Mexico, California Acad. Sci. Proc., vol. 7, pp. 125–156, pls. 17–26*a*, 1917 (date printed with title July 30, 1917; received by me Oct. 16, 1917).

information on Central American between Mexico and Panama, nor is there any on northern South America.

H. Douvillé [1] has referred the "couches de San Fernando" of Trinidad to what he designates "Chattien et Tongrien" or "Stampien supérieur." The species of Foraminifera occurring at this horizon, according to Douvillé, are *Nummulites* cf. *N. vascus*, *Lepidocyclina* (*Isolepidina*)[2] *pustulosa*, *L.* (*Isolepidina*) "du type ogival," *L.* (*Eulepidina*) *formosa*, *L.* (*Eulepidina*) cf. *L. dilatata*. The species in Panama that would represent about the same horizon, according to my interpretation, are *Lepidocyclina panamensis* and *L. multiplicata*, stations 6586*e* and 6587 (see page 555). *L. panamensis*, it should be stated, may range upward into the Emperador limestone, but this is not certain.

The evidence for Barbados is not altogether decisive. Franks and Harrison [3] present the following classification of the Barbadian formations:

Pleistocene and Pliocene	Low-level reefs. High-level reefs. *Globigerina*-marls.
	Break.
Miocene	Oceanic series.
	Break.
Eocene or Oligocene	Scotland beds.

The *Globigerina*-marls are referred to in the section on page 544 of the paper cited, as the Bissex Hill "beds." The only comment I will here make on this section is that it seems to me physically impossible to have a fringing reef conformably built on *Globigerina* ooze deposited in water 1,000 fathoms deep.

After bringing to bear on the problem of the age of the Scotland beds the information accumulated by R. J. L. Guppy, Harrison and Jukes-Browne, and others, as well as that obtained through his own studies, Gregory says:[4] "It is therefore advisable at present to correlate the whole of the beds in Barbados below the Oceanic Series with the San Fernando or Naparima marls of Trinidad. Guppy has recently referred these (and the lower part, at least, of the Scotland beds, goes with them) to the Eocene. They are, however, now generally assigned to the Oligocene, as, for example, by Heilprin."

A preceding paragraph of this paper contains Douvillé's correlation of the "couches de San Fernando" of Trinidad, with the "Stampien

[1] Les Orbitoïdes de l'île de la Trinité, Comptes. Rend., vol. 116, pp. 87–92, 1915.

[2] This subgeneric name is invalid, for it is proposed for *Lepidocyclina mantilli*, which is the type-species of *Lepidocyclina*. The name should be written *Lepidocyclina* (*Lepidocyclina*) *pustulosa* or [*Lepidocyclina*] *Lepidocyclina pustulosa*.

[3] Franks, G. F., and Harrison, J. B., The *Globigerina*-marls [and basal reef-rocks] of Barbados, with an appendix on the Foraminifera by F. Chapman, Geol. Soc. London Quart. Journ. vol. 54, pp. 540–555, 1898.

[4] Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, pp. 255–310, pl. 11, 1895.

supérieur," which is Rupelian. Should the correlation of the Scotland "beds" with the San Fernando be valid, the Scotland "beds" are of the same age as the Antigua formation of Antigua, and corroborates the opinion expressed by Gregory.

Allusion will here be made to two species of fossil corrals, that were submitted to me by Dr. J. W. Spencer and were said to have been collected in Barbados, near the Cathedral at Bridgetown; and I gave him the generic names used in his paper referred to below.[1] The specimens are no longer accessible to me, but I have photographs of the species I listed as *Astrocoenia* species, which is the species to which I have applied the name *Astrocoenia portoricensis*, page 350 (pl. 76, figs. 4, 4*a*, pl. 78, figs. 1, 1*a*) of this volume; and I have notes on the other species, referred to by me as *Stylophora*, species. The latter species, as well as *Astrocoenia portoricensis*, is exceedingly abundant in Antigua, where I collected between 60 and 70 specimens. It has six septa and a styliform columella, characters that led me to refer it to *Stylophora*, but as there are well-developed styles in the corners between many corrallites, I am now placing it in *Stylocoenia*. As these two species not only occur in Antigua, but as the matrix, yellowish clay, in which the specimens were embedded is similar to that usual in Antigua, I have wondered if the specimens did not really come from that Island, and not from Barbados.

Messrs. Harrison and Jukes-Browne, it seems, became much excited over the reported occurrence in Barbados of the two species of corals mentioned above.[2] I will not enter the controversy between these authors and Doctor Spencer further than to say that if the two species whose tentative identification I gave Doctor Spencer actually came from Barbados, their evidence is decisive as to beds of the age of the Antigua formation being in Barbados, and that the evidence of the corals is in accord with Gregory's correlation of the Scotland "beds"; but if the specimens were obtained at the locality at which Doctor Spencer says he found them, the Scotland "beds" must be very near the surface in Bridgetown, and the veneer of the elevated coral-reef limestone decidedly thin. The area 2.75 miles northeast of Bridgetown is indicated on Messrs. Harrison and Jukes-Browne's geological map of Barbados as "limestone probably underlain here by Scotland beds." Careful search should be made for corals in the material underlying the elevated reef in Bridgetown, and if the older coral-fauna is there, additional specimens will almost certainly be found, for the two species reported from there are usually represented not by occasional but by numerous specimens, if present at all.

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[1] Spencer, J. W., On the geological and physical development of Barbados; with notes on Trinidad, Geol. Soc. London Quart. Journ., vol. 58, pp. 354–365, 1902.

[2] Harrison, J. B., and Jukes-Browne, A. J., The geology of Barbados, Geol. Mag., vol. 9, pp. 550–554, Dec. 4, 1902.

According to Hill[1] this epoch is represented in Jamaica by an erosion unconformity that intervenes between the Montpelier white limestone and the Bowden marl. The orbitoids and nummulites of Jamaica are greatly in need of critical study. It is entirely probable that part of Hill's Montpelier limestone is of middle Oligocene (Rupelian) age.

UPPER OLIGOCENE.

It is my opinion, as expressed on a previous page (555), that the upper part of the Culebra formation and the Emperador limestone are the correlatives of the European Aquitanian, and on page 571 I have given my reasons for preferring to refer the Aquitanian to the upper Oligocene rather than to the basal Miocene. The reference of the upper part of the Culebra formation, in which *Lepidocyclina canellei* R. Douvillé and Lemoine and *L. chaperi* R. Douvillé and Lemoine occur, to the upper Oligocene is old, for it was first published by H. Douvillé in 1898.[2] Later[3] he refers the beds in which *L. canellei* is found to the upper Aquitanian, which he considers lower Miocene. M. Douvillé apparently is confused as regards the stratigraphic relations of *L. chaperi*, for the section, station 6019*e–f*, page 538, shows that it occurs stratigraphically above *L. canellei*, station 6019*a*, page 538, in Gaillard Cut.

As has been said, I correlate that part of the Culebra formation in which *Lepidocyclina canellei*, *L. chaperi*, *L. vaughani*, *Heterosteginoides panamensis*, *Nummulites panamensis*, *Orbitolites americana*, and the corals listed on page 208, with the upper half of the Chattahoochee formation of Georgia and Florida and a part of the Tampa formation of Florida, and I consider it the American correlative of the European Aquitanian-Chattian.

The Emperador limestone is paleontologically very closely related to the underlying top of the Culebra formation. In fact, except in the Canal Zone, where they are separable because of lithologic differences, it seems to me doubtful if the horizons represented by them can be positively identified.

As a part of my discussion of the fossil corals it was necessary for me to discuss the geographic distribution of coralliferous deposits of this age in America. Besides those in Panama, marine deposits of the same age also occur in Anguilla, probably in Porto Rico, in Cuba, Florida, and Georgia, and H. Douvillé's researches on the Foraminifera of Trinidad show their presence on that island. It is probable that they are also present in Martinique, Santo Domingo, and eastern Mexico, but precise data are lacking.

[1] Hill, R. T., The geology and physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, p. 143, 1899.

[2] Douvillé, H., Sur l'âge des couches traversées par le Canal de Panama, Soc. Géol. France Bull., vol, 26, pp. 587-600, 1898.

[3] Douvillé, H., Les couches à orbitoïdes de l'isthme de Panama, Idem., séance du 20 décembre 1915, pp. 129-131, 1916.

Recently Dr. Sidney Powers has presented to the United States National Museum some specimens he collected at the entrance to Rio Dulce, Guatemala. The rock is a massive light-colored, fine-textured limestone, with a conchoidal fracture, and contains many poorly preserved fossils. Among the fossils are *Orbitolites* species; several corals, one of which resembles *Siderastrea*, another is probably a specimen of *Goniopora*, and a third seems to be a branching poritid coral that looks precisely like a coral obtained by Doctor MacDonald in limestone, referred by him to the Emperador limestone, in the swamp north of Ancon Hill and about one-quarter of a mile south of Diablo Ridge, Canal Zone; and there are specimens of *Ostrea*, *Pecten*, and *Lima*. This material is too poor to warrant a positive opinion, but it is worth noting, and it probably represents a horizon very near that of the Emperador limestone.

According to Hill's account of the stratigraphic succession in Jamaica, the correlatives of these uppermost Oligocene deposits are represented there by a stratigraphic break, the unconformity between the Montpelier white limestone and the Bowden marl.

MIOCENE.

The definite correlation of the Canal Zone Miocene with European horizons was first attempted by H. Douvillé in his paper, already cited, on the age of the deposits along the Panama Canal. He says regarding the deposits overlying those discussed in the foregoing remarks: "Leur âge est incontestablement Miocène."[1] He considers the lower part of these deposits as Burdigalian, the upper part as Helvetian in age. That part of the Gatun formation exposed at Monkey Hill is referred to the Helvetian.

The literature on the age of the Gatun formation is considerable, but a lengthy review of it appears unnecessary. The papers by Toula and by Pilsbry and Brown have already been cited on page 560 of this volume. Actually there is in most cases more apparent than real discrepancy between the correlations of the different investigators, due to the fact that the Alum Bluff formation, including the Chipola marl member at its base, has been referred to the upper Oligocene. The Alum Bluff formation is certainly of Miocene age, according to European usage, and is the American equivalent of the Burdigalian. All available evidence indicates that the lower part of the Gatun formation in the Canal Zone is the equivalent of the Alum Bluff formation of Florida and Georgia. Although the Gatun formation contains numerous species of Foraminifera, echinoids, and Crustacea, the fauna is predominantly molluscan, and the discrimination of zones within it must await the completion of the study of the careful zonal collections Doctor MacDonald and I

[1] Soc. Géol. France Bull., vol. 26, p. 599, 1898.

made. At present I have not strong evidence, but it is nevertheless my belief that, while the lower part of the formation is of Burdigalian, the upper part is of Helvetian age, as Douvillé in essence said so long ago as 1898. This would still signify that the Gatun formation is geologically older than the Miocene of the Chesapeake group in Maryland and Virginia and the Marks Head, Duplin, and Choctawhatchee marls of the Carolinas, Georgia, and Florida.

Deposits of old Miocene (Burdigalian = Alum Bluff) age are widely distributed around the perimeters of the Gulf of Mexico and the Caribbean Sea. The Gatun formation extends from Panama into Costa Rica on one side and into Colombia on the other. The lists of corals, Bryozoa, and Crustacea already given show the extension into Costa Rica. Pilsbry and Brown [1] say regarding a collection from near Cartagena, Colombia, that it is from beds "about equivalent in age to the Gatun in the Canal Zone." They record the following species:

Fossil mollusks from near Cartagena, Colombia.

Conus proteus Hwass.
molis Brown and Pilsbry.
imitator Brown and Pilsbry.
aemulator Brown and Pilsbry.
gaza Pilsbry and Johnson.
Turris cartagenensis Pilsbry and Brown.
Drilla gatunensis Toula.
Cancellaria dariena Toula.
Mitra longa Gabb.
Marginella mediocris Pilsbry and Brown.
Oliva sayana immortua Pilsbry and Brown.
Strombina cartagenensis Pilsbry and Brown.
lloydsmithi Pilsbry and Brown.
Solenosteira dalli Brown and Pilsbry.
Murex gatunensis Brown and Pilsbry.
pomum Gmelin.
Typhis linguiferus Dall.
Cassis monilifera Guppy.
Polinices mammillaris (Lamarck).
Potamides avus Pilsbry and Brown.
Turritella cartagenensis Pilsbry and Brown.
lloydsmithi Pilsbry and Brown.
subgrundifera Dall.
tornata Guppy.
Petaloconchus domingensis Sowerby.
Dentalium solidissium Pilsbry and Brown.
cartagenense Pilsbry and Brown.
Pitar (*Hysteroconcha*) *casta* Pilsbry and Brown.
Yoldia pisciformis Pilsbry and Brown.
Arca consobrina Sowerby.
Glycymeris tumefactus Pilsbry and Brown.
trilobicosta Pilsbry and Brown.
lloydsmithi Pilsbry and Brown.
Ostrea sculpturata osculum Pilsbry and Brown.

In 1916, Mr. George C. Matson was engaged in geologic work in northern Colombia, near Usiacuri, and sent to the United States National Museum collections of fossils for use in comparing with those from the Canal Zone and Costa Rica. Dr. C. W. Cooke, before being detailed to other work, had prepared preliminary lists of the species of mollusks received up to the time he had to undertake other duties.

[1] Pilsbry, H. A., and Brown, A. P., Oligocene fossils from the neighborhood of Cartagena, Colombia, with notes on some Haitian species, Philadelphia Acad. Nat. Sci. Proc. for 1917, pp. 32–41, pls. 5, 6, 1917.

Preliminary list of fossils from Colombia.

(All determinations subject to revision.)

By CHARLES WYTHE COOKE.

7852. Las Sierras, between el Carmen and Zambrano; from surface on top of knoll. F. L. Wilde, collector, December 8, 1916.

Conus, probably *C. imitator* Brown and Pilsbry.
2 species.
Terebra gatunensis Toula.
subsulcifera Toula.
Drillia gatunensis (Toula)?
Turris barretti (Guppy)?
Cancellaria dariena trachyostraca Brown and Pilsbry?
2 species.
Oliva gatunensis Toula?
Marginella species.
Latirus aff. *L. protractus* (Conrad).
Strombina gatunensis (Toula).
Distorsio gatunensis Toula.
Turritella gatunensis Conrad.
altilira Conrad.
mimetes Brown and Pilsbry.
species.
Architectonica gatunensis (Toula).
Natica, several species.
Cheilea princetoniana Brown and Pilsbry?
Crucibulum species.
Arca.
species.
Pecten species.
Corbula (*Cuneocorbula*) *hexacyma* Brown and Pilsbry.
Chama species.
Veneridae, several species.

Correlation: Gatun formation.

7873. About one-half kilometer east of Usiacuri, Colombia. G. C. Matson, collector.

Septastrea matsoni Vaughan.
Terebra cf. *T. gausapata* Brown and Pilsbry
gatunensis Toula.
Conus dalli Toula.
2 species.
Turritidae, several species.
Cancellaria, 3 species.
Olivella, several species.
Mitra longa Gabb?
Fusinus species.
Latirus species.
Alectrion species.
Columbellidae, several species.
Murex species.
Typhis species.
Turritella mimetes Brown and Pilsbry.
altilira Conrad.
gatunensis Conrad.
Petaloconchus domingensis Sowerby?
Natica species (very close to a species from Shell Bluff, Shoal River, Florida).
Natica, 2 species.
Neretina species.
Niso species.
Pyramidella species.
Architectonica gatunensis Toula.
Capulus species.
Calyptrea species.
Glycymeris new species.
Arca aff. *A. grandis* Brown and Pilsbry.
Arca new species.
Ostrea species.
Pecten species.
Amusium large species.
Venericardia species.
Chione species.
Corbula, 2 species.
Mactra species.

Correlation: Gatun formation.

7855. Two kilometers west of Usiacuri, Colombia.

Arca aff. *A. grandis* Broderip and Sowerby.

Correlation: Probably Gatun formation.

7856. Three kilometers north of Usiacuri, Colombia.

Oliva species.
Cancellaria species.
Petaloconchus dominigensis Sowerby?
Turritella gatunensis Conrad.
species.
Glycymeris species (also at 7873).
Arca aff. *A. grandis* Broderip and Sowerby
Ostrea species.
Pecten species.
Anomia species.
Basta species.
Cardium species.
Chione species.
Barnacle.

Correlation: Probably Gatun formation.

7874. River bed at Usiacuri, Colombia. G. C. Matson, collector.
Ostrea species, like that at station 7859.

7857. Weathered surface of calcareous hard sandstone at San Antonio, 18 miles east of Tenerife, Colombia. Rogers and Wilson, collectors.

Terebra 2 species.
Turris, like *T. albida* (Perry).
Cancellaria cf. *C. guppyi* Gabb.
Turritella altilira Conrad.
Cerithium, 2 species.
Chama species, etc.

7858. Creek bed at San Antonio. Same bed as 7857.

Cerithium species.
Scapharca species.

7859. Creek at San Antonio.

Scapharca cf. *S. chiriquiensis* (Gabb).
Ostrea species, etc.

Other material was forwarded by Mr. Matson, but it has not been examined.

Marine deposits of similar age are found in Venezuela at Cumana and in Trinidad. R. J. L. Guppy has published two interesting papers [1] in which he compares the species found at Springvale, Trinidad, with species from Cumana (Venezuela), Jamaica, and Haiti. Douvillé, in his account of the orbitoids of Trinidad, places the "couches de Cumana à *Turritella tornata*" in the Burdigalian.

The "Oceanic Series" of Barbados (see p. 583 of this paper) is referred to the Miocene by all the recent students of that island. They are deposits supposed to have been laid down in water at least 1,000 fathoms deep, as they contain beds of radiolarian earth and specimens of a deep-sea echinoid, *Cystechinus crassus* Guppy.

H. Douvillé reports *Lepidocyclina giraudi* R. Douvillé from the "Burdigalien de la Martinique." [2] Subsequently (p. 591) Mollusca from Martinique, thought by M. Cossmann to represent a higher horizon, will be considered.

[1] Guppy, R. J. L., On a collection of fossils from Springvale, near Couva, Trinidad, Trinidad Agric. Soc. Paper No. 440, pp. 15, 1911; Fossils from Springvale, near Couva, Trinidad, Idem., Paper No. 454, pp. 10, 3 pls., 1911.

[2] Comptes Rend., vol. 161, p. 89, 1915.

Dall said, in 1903, regarding the age of the Bowden marl of Jamaica:[1] "It is perhaps with the Oak Grove sands, or between the Chipola and the Miocene, that the position of the Bowden fauna would be marked most plausibly against the Tertiary column of Florida formations."

This correlation has essentially been made by students of other groups of organisms, but instead of considering the Bowden of Oligocene age, they refer it to the Miocene. W. P. Woodring, in a recently published summary of his conclusions based upon a study of the Bowden pelecypods,[2] says: "Though many of the post-Chipolan elements are found among the characteristically tropical groups, yet the introduction of superspecific groups, some of which are not exclusively tropical, can hardly be disregarded. The Bowden pelecypods are distinctly younger than those of the Alum Bluff faunas, as these faunas are now known. It may be suggested that the Bowden fauna is Burdigalian, that is, lower Miocene in the sense of most American stratigraphers."

Dr. J. A. Cushman, from his study of the Foraminifera, and Messrs. Canu and Bassler from their investigations of the Bryozoa consider the Bowden fauna Miocene. My opinion, based upon the fossil corals (see pp. 212, 213 of this volume), is the same as that of the authors mentioned. Until the results of Miss Gardner's work on the Mollusca of the Alum Bluff formation are tabulated and comparisons made with the Bowden fauna, only approximate correlation is practicable. It is my opinion that the Bowden is equivalent to a horizon high in the Alum Bluff, perhaps about that of the Shoal River marl. In other words, the Bowden corresponds to upper rather than to lower Burdigalian.

There are in Santo Domingo at least three Miocene horizons, according to the results recently obtained there by Miss C. J. Maury.[3] She transmitted the Foraminifera, corals, echinoids, and Bryozoa to me for study in connection with the investigation of the stratigraphic paleontology of Central America and the southern United States, and Miss M. J. Rathbun has delivered to me a manuscript in which she has included descriptions of the fossil Crustacea collected by Miss Maury. Besides Miss Maury's report on the Mollusca, I am able to use Doctor Cushman's report on the Foraminifera, my own on the corals, Doctor Jackson's on the echinoids, Messrs. Canu and Bassler's on the Bryozoa, and Miss Rathbun's on the Crustacea. Miss Maury's zone H on Rio Cana is the same horizon as the Bowden; and she considers her zones G and I to be the same

[1] Dall, W. H., Tertiary fauna of Florida, Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1582, 1903.

[2] Woodring, W. P., The pelecypods of the Bowden fauna, Johns Hopkins Univ. Circular, March, 1917, pp. 242-254, 1917.

[3] Maury, Carlotta J., Santo Domingo type sections and fossils, Bull. Amer. Paleontology, vol. 5, pp. 165-459, pls. 28-65, 1917.

horizon as her zone H. The age of the Santo Domingan corals is discussed on page 218 of this volume. The Foraminifera, among which are no orbitoids, and the Bryozoa, both groups abundantly represented, give essentially the same result as the corals. Messrs. Canu and Bassler consider the Bryozoa from zones H–I as of unquestionably Burdigalian age.

This same horizon, that of the Bowden, has been recognized at numerous places in Cuba, as has been stated in discussing the fossil coral faunas of Cuba (p. 218). It has been identified at Baracoa and Matanzas, and perhaps at Havana and Santiago. The lower (Alum Bluff) Miocene of the southeastern United States has been discussed at some length on pages 572–574. Marine deposits of this age occur in Florida, Georgia, and southern Alabama; in Mississippi they are represented by the nonmarine, plant-bearing Hattiesburg clay.

A fauna of very nearly the same, if not identical, age occurs on the Isthmus of Tehauntepec. It has been particularly considered by Böse and Toula.[1] Böse says, regarding the specimens collected by him: "Eine ganze Reihe von Arten steht solchen nahe, die nur aus dem Oligocän der Antillen bekannt worden sind." Although precise correlation of this material is not now practicable, it seems that a lower Miocene horizon is represented.

Dr. C. W. Hayes collected on the Pacific coast of Nicaragua, 75 miles northwest of Brito Harbor, station 6409, worn specimens of a species of bryozoan that Dr. R. S. Bassler says is apparently *Cupularia canariensis* Busk, which ranges from a horizon in the Alum Bluff formation to Recent. The matrix is a calcareous, sandy, consolidated marl, and was included by Hayes in his Brito formation. The age of these specimens is not older than, and it probably is, old Miocene. The Brito formation, therefore, includes deposits ranging stratigraphically from upper Eocene to lower Miocene, but the beds at the type locality are of upper Eocene age (see previous pp. 193–197).

It was stated on page 586 that H. Douvillé considered that part of the Gatun formation exposed around Mount Hope as Helvetian Miocene, and that I provisionally accept his determination. It is probable that some of the Miocene deposits of northern Colombia are also of this age. Information on Venezuela and between there and Martinique is lacking.

For Martinique we have the following statement from Cossmann:[2]

D'après un premier aperçu qui ne porte que sur une partie des Siphonostomes, il praît à peu près certain qu'un grand nombre de Gastropodes se trouvent à la fois dans

[1] Böse, E., Zur jungtiären Fauna von Tehuantepec. I. Stratigraphie, Beschreibung und Vergleich mit americhanischen Tertiärfaunen, K. k. geolog. Reichsanst. (Wien) Jahrb., vol. 60, pp. 215-255, pls. 12, 13, 1910.

Toula, F., Zur jungtertiären Fauna von Tehuantepec. II. Vergleichung hauptsächlich mit europäischen und lebenden Arten, Idem, vol. 60, pp. 255-276, 1910.

[2] Cossmann, M., Étude comparative de fossiles miocèniques recuellis à la Martinique et à l'isthme de Panama, Journ. conchyliologie, vol. 61, pp. 1-64, pls. 1-5, 1913.

les deux gisements, et que leur âge est au-dessus des couches de Bowden à la Jamaïque, qui ont fait l'objet d'une étude de la part de Guppy. Ces dernières renferment une très belle faune dont j'ai pas mal de spécimens dans ma collection: sans aller jusqu'à partager complètement l'opinion de M. Dall qui les rapporte à l'Oligocène, je crois qu'elles représentent l'équivalent de notre Aquitanien, c'est-à-dire le Miocène inférieur, tandis, que les fossiles de la Martinique et de Gatun (Panama) seraient un peu plus récents, probablement du Miocène moyen. Enfin, d'après les matériaux que j'ai pu étudier à l'École des Mines, les fossiles de Saint-Domingue (Haïti), étudiés par Gabb at par Sowerby, représenteraient un niveau déjà plus élevé, celui du Miocéne supérieur.

M. Cossmann considers this material from Martinique as younger than the Bowden fauna.

Precise information on the paleontology of the Tertiary formations of Guadeloupe is exceedingly meager, in fact it is almost nothing. Dr. J. W. Spencer submitted to me a specimen of *Stylophora*[1] collected by him in a limestone near Les Abîmes. Accurate identification of a species of *Stylophora* may be a proper basis for precise correlation, but the genus ranges from upper Eocene to middle Miocene (about Helvetian) in the West Indian Tertiaries. In 1849 Milne Edwards and Haime described a coral from the "Terrain tertiare" of Guadeloupe, under the name *Thecosmilia ponderosa*, and subsequently transferred it to the genus *Montlivaltia*.[2] I have photographs of the type of this species, kindly sent me by my friend Dr Charles Gravier of the Muséum d'Histoire Naturelle, Paris. It belongs to the genus *Antillia* and is closely related to *A. bilobata* Duncan. *Montlivaltia guesdesi*, described by Duchassaing and Michelotti[3] from Guadeloupe and said to be associated with *Antillia ponderosa*, is also a species of *Antillia*. *A. guesdesi* is so similar to *A. bilobata* that Duchassaing and Michelotti placed the latter in its synonomy. As I have seen no specimens of *A. guesdesi*, I must base any opinions concerning it upon its authors' figures and descriptions. It seems to me different from *A. bilobata*, but as the distinction between the two consists in the relative number of teeth within 1 centimeter on the septal margins, and as the details of the figures of *A. guesdesi* may be inaccurate, it would be improper to insist that they are different. However that may be, there are in Guadeloupe two supposed, very nearly related species of *Antillia*, and they are actually or almost indistinguishable from species that occur in Santo Domingo at a horizon near or above that of the Bowden marl. The evidence for Guadeloupe, therefore, indicates the presence there of deposits of uppermost Burdigalian or Helvetian age. There may be Tertiary deposits both older and younger than the bed in which the specimens of *Antillia* were collected. Doctor Spencer's structure section across the island strongly suggests that such deposits are there.

[1] Spencer, J. W., On the geological and physical development of Guadaloupe, Geol. Soc. London Journ., vol. 57, pp. 506–519, 1901.

[2] Hist. nat. Corall., vol. 2, p. 312, 1857.

[3] Mèm. corall. Ant., p. 69 (of reprint), pls. 5, fig. 13, 1860.

It has already been stated that the fossils obtained by Miss Maury in Santo Domingo at horizons higher than her zones G, H, and I are younger than the Bowden fauna. A line of demarcation between the Burdigalian and higher Miocene is not at present practicable, but it is almost, if not quite, certain that her upper zones are not older than Helvetian. This would still seem to indicate a horizon below the lowest formation of the Chesapeake group of Maryland and Virginia and the Marks Head marl of eastern Georgia, but the available data do not warrant a positive opinion. However, it appears that the higher Miocene deposits of the Santo Domingan section are represented in Florida and Georgia by the erosion interval between the deposition of the uppermost beds of the Alum Bluff formation and that of the overlying Marks Head marl.

The presence in Cuba of deposits, the La Cruz marl, of the same age as the Santo Domingan deposits above Miss Maury's zones H–I, was noted on page 219 of this volume.

It seems that there are in the southeastern United States no Miocene marine deposits of the same age as the upper part of the Gatun formation, the Santo Domingan deposits above Miss Maury's zones H–I, and the La Cruz marl of Cuba, unless some of the latter deposits are younger than is at present supposed.

Except for the Isthmus of Tehuantepec, there is no information on marine Miocene formations of this age in eastern Mexico, or in the area between Yucatan and Costa Rica. The extension of the Gatun formation into Costa Rica has already been discussed.

PLIOCENE.

The Toro limestone is the only formation within the Canal Zone that is supposed to be of Pliocene age. The determination of the age of this formation is necessarily by means of its stratigraphic relations, as only one identifiable species of fossil, *Epitonium toroënse* Dall, was collected in it, but the stratigraphic relations, described by Doctor MacDonald on pages 544, 545 of this volume, are such that the formation can scarcely be of any age other than Pliocene.

The Pliocene deposits in the vicinity of Limon, Costa Rica, were first observed by W. M. Gabb,[1] who described a number of species from there, and they were later visited by R. T. Hill,[2] who made additional collections, on which Doctor Dall supplies notes published in the paper cited.[3] Doctor Dall has recently described an interesting species of *Pecten*, *P. pittieri*,[4] collected by Mr. H. Pittier at Moin Hill, near Port Limon. This species will be referred to in

[1] Gabb, W. M., Descriptions of new species of fossils from the Pliocene clay beds between Limon and Moén, Costa Rica, together with notes on previously known species from there and elsewhere in the Caribbean area, Acad. Nat. Sci. Philadelphia Journ., ser. 2, vol. 8, pp. 349–380, figs. on pls. 45–47, 1881.

[2] Mus. Comp. Zoöl. Bull., vol. 28, p. 234, 1898.

[3] The geologic history of the Isthmus of Panama and portions of Costa Rica, Mus. Comp. Zool. Bull., vol. 28, p. 274, 1898.

[4] Smithsonian Misc. Coll., vol. 59, p. 10, 1912.

a subsequent paragraph. Pliocene corals from this locality are considered on page 223.

Mr. George C. Matson collected at Barranquilla, Colombia, some fossils that belong to a fauna younger than that obtained around Usiacuri, and may be of Pliocene age. *Glycymeris*, *Ostrea*, *Pecten*, and *Lucina* are the genera represented.

The Bissex Hill "beds" of Barbados (see p. 583 of this paper) are considered Pliocene in age by Franks and Harrison; but I infer, from his remarks on the Foraminifera, that Chapman inclined to the opinion that they are of Miocene age. I strongly doubt any of the elevated, terraced coral reefs of Barbados being so old as Pliocene, but present evidence is not decisive. The only known extensive Pliocene coral fauna in America is that of the Waccamaw and Caloosahatchee marls of the southeastern United States. This is discussed on page 222 of this volume. I have studied both the specimens on which Gregory based his account of the Barbadian elevated-reef corals and a collection (see p. 255 of this volume) later sent me by Professor Jukes-Browne. All of the species seem to me inseparable from the species at present living in the Caribbean area, except one that was erroneously identified by Gregory as *Lithophyllia walli* (Duncan).

Pliocene deposits have been recognized at very few places in the West Indies; in fact, about the only locality at which there is reasonable surety of there being beds of this age is near Guantánamo, Cuba, where Mr. O. E. Meinzer collected *Pecten pittieri* Dall, identified by C. W. Cooke.

R. T. Hill considers the Jamaican formations, to which he applies the names Manchioneal and Kingston, as Pliocene, and it seems that he is correct, but the evidence adduced is not completely convincing. In other words, from the evidence available, Hill was justified in his age classification of the deposits mentioned, but their paleontology needs more detailed investigation.

The marine Pliocene of the southeastern United States has been considered on page 576 of this paper.

Heilprin was the first to call attention to the extensive Pliocene "gray or white shell limestone" of Yucatan.[1] His examinations were made "at several points in and about Merida, in numerous cuttings along the line of the Merida-Kalkini Railroad, on the line of the railroad connecting the capital city with Ticul, all along the traverse between Merida and Tunkas," and "at various points between Tekanto and Cilam." Sapper has published a rough out-

[1] Heilprin, Angelo, Geological researches in Yucatan, Acad. Nat. Sci. Philadelphia Proc. for 1891, pp. 136–158, 1891.

TENTATIVE CORRELATION TABLE OF THE TERTIARY MARINE SEDIMENTARY FORMATIONS OF PANAMA.

American time subdivisions.		Panama.	Jamaica.	Other Antilles.	Mexico and Central America.	Southeastern United States.	European time subdivisions.
Pliocene.		Toro limestone.	Manchioneal formation. Kingston formation.	Pliocene of Guantanamo, Cuba.	Pliocene of Yucatan and Limon, Costa Rica.	Waccamaw marl, Nashua marl, and Caloosahatchee marl (nearly contemporaneous).	Sicilian. Astian. Plaisancian.
Miocene.	Upper.					Yorktown formation, Duplin marl, and Choctawhatchee marl (nearly contemporaneous).	Pontian. Sarmatian.
						St. Marys formation.	
						Choptank formation.	Tortonian.
						Calvert formation. / Marks Head marl.	
	Middle.			La Cruz marl (Cuba). / Upper horizon in Martinique. / Upper horizon in Santo Domingo.	Gatun formation (Costa Rica). / Pacific coast of Nicaragua. / Exposures on Isthmus of Tehuantapec.		Helvetian.
	Lower.	Gatun formation.	Bowden marl.	Marl at Baracoa, Cuba. / Lower horizon in Martinique. / Zones G, H, and I in Santo Domingo.		Alum Bluff formation: Shoal River marl member. Oak Grove sand member. Chipola marl member.	Burdigalian.
Oligocene.	Upper.	Emperador limestone.		Anguilla formation (Anguilla), and beds at many localities in Cuba.		Chattahoochee formation. / Tampa formation.	Aquitanian. Chattian.
	Middle.	Culebra formation: Upper part of Culebra. / Lower part of Culebra and limestone at Tonosi.		Coral reef at Guantanamo, Cuba. / Antigua formation (Antigua). / Pepino formation (Porto Rico). / Lower horizon in Santo Domingo.	San Rafael formation.		Rupelian.
	Lower.	Limestone with *Orthophragmina* on Haut Chagres[a] and limestone at David (contemporaneous). / Bohio congl.[b]	Montpelier white limestone.		Deposits with *Pecten* aff. *P. poulsoni* and large, discoid orbitoids.	Vicksburg group. / Byram calcareous marl. Marianna limestone. Red Bluff clay.	Lattorfian (Sannoisian).
	Upper.		Cambridge formation. Richmond formation.	St. Bartholomew limestone (St. Bartholomew). Widely distributed in Cuba; also in Haiti.	Brito formation of Nicaragua (typical Brito). / Frio clay. Fayette ss.	Jackson formation. / Ocala limestone.	Ludian (Priabonian). Bartonian.
Eocene.	Middle.	Eocene of Tonosi.			Near the Texas border: Claiborne group.	Claiborne group.	Auversian.[c] Lutetian.
	Lower.				Wilcox formation.	Wilcox group: Hatchetigbee formation. Bashi formation. Tuscahoma formation. Nanafalia formation.	Ypresian.[c] Sparnacian.[c]
					Midway formation.	Midway group: Naheola formation. Sucarnochee clay. Clayton limestone.	Thanetian.[c] Montian.[c]

[a] Reported by H. Douvillé and referred to "Stampien inférieur" = Vicksburgian = Lattorfian; Cushman thinks these deposits should be referred to the upper Eocene and placed opposite the St. Bartholomew limestone in the table.
[b] May belong stratigraphically somewhat higher.
[c] Correlation proposed by E. W. Berry.

line map of the Pliocene area in Yucatan,[1] and he repeated Heilprin's lists of fossils.

No information is available for British Honduras, the Republic of Honduras, or Nicaragua.

The accompanying table presents the approximate stratigraphic equivalence of the Tertiary marine formations in Central America, the Antilles, the southeastern United States, and Europe. It will be noticed that the table indicates two great stratigraphic breaks, namely, one in lower and middle Eocene time, the other in upper Miocene time.

Pre-Tertiary Formations in Central America and the West Indies.

The foregoing discussion of the marine geologic formations of Panama has included more or less consideration of all of those of Tertiary age, concerning which we have knowledge, in the southern United States, eastern Mexico, Central America, and the West Indies, and a few notes have been made on northern South America. Since the publication of Bailey Willis's Index to the stratigraphy of North America,[2] there has been no important addition to our knowledge of the pre-Tertiary formations of the West Indies and Central America. As this volume and the geologic map of North America it was prepared to accompany are both easily accessible to geologists, and as a review of the formations of those ages would be mostly repetition of information contained in that work, I will make only a few general remarks.

Rocks of supposed Archean age outcrop as follows: State of Oaxaca, Mexico, granites and gneisses; Chiapas and Guatemala, granites, talc, and chloritic schists; Nicaragua and Honduras, fundamental granite; Venezuela, granite from Puerto Cabello to Trinidad. Granitic débris was found in Eocene sediments in Costa Rica and along Rio Chagres in Panama by Hill. There is granite overlain by arkose below the Upper Cretaceous near the city of Santa Clara, Cuba, and marble and schists in the Isle of Pines.

Paleozoic rocks of undertermined age occur in northern Sonora, Mexico, and in Chiapas; in Guatemala there are formations of both pre-Carboniferous and Carboniferous age; Mierisch reports Devonian in northern Nicaragua; and Paleozoic rocks apparently are present in Honduras. The rocks, largely serpentine, forming the proto-axis of Cuba, and some of the formations in the Trinidad Mountains, Cuba, may be of Paleozoic age, but there is no definite proof.

Triassic deposits occur near Zacatecas, and perhaps at Miquehuana, State of Tamaulipas, Mexico; the Todas Santos formation in Chiapas and Guatemala is of Triassic age, and it appears, according to Mierisch,

[1] Sapper, Carlos, La geografía física y la geología de la Península de Yucatan, Mexico Instit. geolog. Bol. No. 3, pp. 57, 6 pls., 1896.

[2] U. S. Geol. Survey Prof. Paper 71, 1912.

also to occur in northern Nicaragua. Sapper records Triassic rocks from several areas in Honduras.

Jurassic limestone froms the axis of the Organos Mountain, Province of Pinar del Río, Cuba; and marine Jurassic is extensively developed in Mexico and west Texas.

The Lower Cretaceous, so greatly developed in Mexico and Texas, is not known in the West Indies or in Central America proper, that is, below the Isthmus of Tehuantapec, except in Honduras.[1]

With regard to the Upper Cretaceous, it will be said that the peculiar Upper Cretaceous fauna of Jamaica has been found in Cuba and St. Thomas. Hill has noted in Porto Rico "volcanic tuffs and conglomerates with interbedded Cretaceous rudistean limestone similar to that of Jamaica," thereby confirming a previous inference of Cleve that the horizon he recognized in St. Thomas also occurs in Porto Rico; and it is reported from the Island of Haiti. Quin figures a specimen of *Barrettia* from the "Blue-beach" formation of St. Croix (but without recognizing its affinities); and Sapper records *Barrettia* from northwest of Coban, Guatemala, and a somewhat similar fauna from Chiapas, Mexico. As Cleve years ago pointed out, this fauna is more closely related to that of Gosau, Austria, than to any in North America north of the Gulf of Mexico. Hill reports Rudistes and Inocerami from his San Miguel formation, Costa Rica, but Romanes[2] doubts the correctness of the identifications.

OUTLINE OF THE GEOLOGIC HISTORY OF THE PERIMETERS OF THE GULF OF MEXICO AND THE CARIBBEAN SEA.

The following pages will present only the broad outlines of the geologic history of the region of which Panama forms a part. The details for Panama are given by Doctor MacDonald in the manuscript of his report on the geology of the Canal Zone and adjacent areas, to be published by the Smithsonian Institution. Three manuscripts on the physiography and stratigraphy of Cuba are now in my possession. One of these is on an area adjacent to Guantanamo, by Mr. O. E. Meinzer; the second is on an area northwest of Guantanamo by Mr. N. H. Darton; and the third is a general account of the physiography and stratigraphy of the entire island and the Isle of Pines by myself. The paleontology of the different formations is considered in as much detail as available information permits. A similar account of the geology of the Lesser Antilles, by Mr. Robert T. Hill and myself, is nearly ready for press, and paleontologic monographs of the fossil biota of St. Bartholomew, Antigua, and Anguilla are almost complete. The geologic history of these

[1] Dr. T.W. Stanton has recently verified the age determination of these deposits. (Oral communication.)

[2] Romanes, James, Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 103–139, pls. 8, 9, 1912.

areas is discussed in the reports mentioned, which I hope may, within a few months, be submitted for publication by the Carnegie Institution of Washington.

The discussion of the age and geographic distribution of the different geologic formations on preceding pages partly prepares the way for an account of the paleogeography of the region under consideration; but before proceeding the geographic relations of the Three Americas should receive attention.

Geographic Relations of the Three Americas.

This subject has attracted many investigators, some of whom considered only segments of the perimeters of the two American seas, the Caribbean Sea and the Gulf of Mexico, while others considered the relations between Central America and the West Indies to the continent of North America, on the north, and to the continent of South America, on the south. Some of the important facts in the alignment of the West Indies were recognized so long ago as 1848, for Schomburgh [1] called attention to the fact that in the Lesser Antilles there are an outer and an inner group of islands, the outer largely composed of calcareous rocks, the inner composed of volcanic rocks. Knowledge of the geographic and geologic relations within this region has grown gradually, and there have been so many contributors to it that no attempt will be made to credit each of them for what he has done. However, special acknowledgments should be made to R. T. Hill for his investigations in a number of the West Indian and Central American areas; to Carl Sapper for his exploration in Yucatan, Tabasco, Chiapas, Guatemala, parts of Honduras, and San Salvador; and to Karsten and Sievers for their work in northern South America. The footnotes [2] below gives the titles of some of the more important publications, and they contain references to earlier literature.

[1] Schomburgh, Sir R., History of Barbados, p. 532, 1848.

[2] Dollfus, A., and Mont-Serrat, E. de, Voyage géologique dans les républiques de Guatemala et de Salvador, pp. 535, 18 pls., 1868, Paris. See particularly pp. 250–258.

Felix, J., and Lenk, H., Ueber die tektonischen Verhältnisse der Republik Mexiko, Deutsch. geolog. Gesellsch. Zeitsch., vol. 44, pp. 303–323, pls. 19, 20, 1892.

Hill, R. T., Fundamental geographic relations of the Three Americas, Nat. Geog. Mag., vol. 7, pp. 175–181, 1896; The physical geography of Mexico [Abstract], Eighth Internat. Geog. Cong. Rept., pp. 765–766, 1905. (See also papers by Hill listed on p. 604, this volume.)

Karsten, Hermann, Géologie de l'ancienne Colombie bolivarienne, Venézuela, Nouvelle-Grenaïde et Ecuador, pp. 62, 1 map, 8 pls., 1886, Berlin.

Sapper, Carl, Grundzüge der physikalischen geographie von Guatemala, Petermanns Mitteil. Ergänzungsbd. 24, Ergänzungsheft 113, pp. 59, 4 maps, 1894; La geografia fisica y la geologia de la peninsula de Yucatan, Mexico Inst. geolog. Bol. 3, pp. 57, 6 pls., 1896; Das nördliche Mittel-Amerika, pp. 436, 8 pls., 1897, Braunschweig; Mittelamerikanische Reisen und Studien aus den Jahren 1888 bis 1900, pp. 426, 4 statistical tables, 4 maps and numerous unnumbered halftone figs. and pls., 1902, Braunschweig; Über Gebirgsbau und Boden des südlichen Mittelamerika, Petermann's Mitteil., Ergänzungs Bd. 32, Ergänzungsheft 151, pp. 82, 4 pls., 1905.

Sievers, W., Karten zur physikalischen geographie von Venezuela, Petermanns Mitteil., vol. 42, pp. 125–129, pl. 10, pp. 149–155, pl. 11; pp. 197–201, pl. 15, 1896.

Suess, E., Les Antilles, La face de la terre (translated under the direction of E. de Margerie), vol. 1 pp. 724–737, 1897.

GENERAL RELATIONS.

The boundaries of the Gulf of Mexico and the Caribbean Sea form a parallelogram (see pl. 73); those on the north and south extend along east and west lines, those on the east and west are northwest to southeast, while the basins are separated by east and west structures.

The bottoms of the continental slopes on both sides of the continents range between 2,500 and 3,000 fathoms in depth. On the east the 2,500-fathom curve is either at or near the base of the slope from off the Banks of Newfoundland southwestward to off Jacksonville, Florida, whence it bends toward the southeast, passing east of the Bahamas, north of Porto Rico, east of the Caribbean arc, east of Trinidad, and northeast of the Guianas. The 2,500-fathom contour lies farther offshore on the Pacific side than on the Atlantic side of North America, but is nearer shore from the Revilla Gigedo Islands, west of Manzanillo, Mexico, to off Guatemala, whence southward the 2,000-fathom contour is near the base of the slope until off Peru, where there is a drop to over 3,000 fathoms in the great Callao deep.

Land areas bound the Gulf of Mexico on the east, north, west, and south. The land on the west continues without interruption through Central America and northern South America, forming the western and southern boundaries of the Caribbean Sea. Between southern Florida and Trinidad there are relatively shallow-water connections with the Atlantic Ocean through passages between Florida and Cuba, and through passages between both the Greater and the Lesser Antilles to Trinidad. Depths of about 1,000 fathoms or somewhat more are found between Cuba and Haiti in the Windward Passage, and between Anegada and Anguilla in the Anegada Passage, but they are usually less than 500 fathoms.

The Gulf of Mexico is separated from the Caribbean Sea by the Yucatan Peninsula and Cuba, but connects with it through the Yucatan Channel. The deepest part of this basin, which is a simple basin, is slightly over 2,000 fathoms.

The Caribbean Sea is a compound basin, separated into two parts by the ridge that extends from Honduras to Jamaica. The northern division is almost subdivided by the Cayman ridge, which extends westward from the Sierra Maestra of Cuba. Depths of 2,500 fathoms are attained between the Caymans and Cape San Antonio, Cuba, while south of them depths exceeding 3,000 fathoms are recorded in the Bartlett deep. The southern division is a simple basin with depths ranging between 2,250 and 2,900 fathoms.

The data presented show that these two basins are land-locked, except that between Florida and Trinidad shallow passages between land areas connect with the Atlantic Ocean, that the two basins are separated by structures transverse to the continental trend in Yucatan

and Cuba, and that the Gulf of Mexico is a simple while the Carribbean Sea is a compound basin.

The major tectonic features surrounding and occurring within the basins will now be briefly considered.

TECTONIC PROVINCES.

In order to give an adequate conception of the relations of the two basins the general features of both the North and South American continents must be considered as well as the details of the land areas and submarine banks and ridges immediately adjacent to and within the region. The provinces germane to the area will be more particularly considered, while the boundaries of those more remote will be only indicated. Twelve major with several subordinate provinces may be discriminated as follows:

1. Bahamas.
2. Atlantic and Gulf Coastal Plain.
3. Mexican Plateau.
4. Oaxaca-Guerrero.
5. Yucatan.
6. Guatemala—Chiapas.
7. Cuba and northern Haiti.
8. Honduras, and its continuation to Jamaica, southern Haiti, Porto Rico, the Virgin Islands, and the outlying island of Saint Croix.
9. Costa Rica–Panama.
10. Andes.
11. Maritime Andes.
12. Caribbean Islands:
    - 12*a*. Barbadian Ridge.
    - 12*b*. Main Caribbean Arc.
    - 12*c*. Aves Ridge.

1. *Bahamas.*—The Bahama Islands and their accompanying shoals occupy a triangular area which lies east of Florida and north of Cuba and Haiti. The islands either occur on one of two large banks, the Little Bahama and the Great Bahama banks, or they rise to the southeast of the latter bank as isolated eminences separated by water as much as 1,000 fathoms in depth. Two bodies of water over 1,000 fathoms deep, Exuma Sound and The Tongue of the Ocean, indent the Great Bahama Bank. Water 1,000 fathoms in depth is close to the eastern shore of the Bahamas as far north as Elbow Cay on Little Bahama Bank. Eastward from the 1,000-fathom curve the bottom rapidly descends to a depth between 2,000 and 3,000 fathoms. The Bahama Islands are subaerial protuberants above the nearly level, slightly submerged surfaces of extensive plateaus which on one or more sides rise precipitously from oceanic depths.

2. *Atlantic and Gulf Coastal Plain.*—This plain extends beyond Rio Grande to the Sierra Madre, Mexico, and as far southward as Tampico. A narrow, more or less broken plain continues beyond Vera Cruz to the lowland plain of Yucatan, where it meets the transverse Oaxaca-Guerrero structural line.

Throughout its extent, notwithstanding irregularities in surface configuration, the Coastal Plain in general slopes from its landward margin to the edge of the Continental Shelf. The inner margin ranges from 300 to 600 feet in altitude between Maryland and central Texas; while in west Texas it attains a height of slightly more than 1,000 feet above sea level.

3. *Mexican Plateau.*—At least four provinces of major rank are recognized in the western Cordilleran region of the United States, according to Ransome,[1] namely: (1) The Rocky Mountains, (2) the Colorado Plateau, (3) the Nevada-Sonoran region, (4) the Pacific ranges. Nos. 1 and 2 are parts of the Laramide mountain system; No. 3 is the intermontane belt; and No. 4, the Pacific mountain system. Fenneman dissents from this classification in that he refers the Colorado Plateau to the Intermontane plateaus, along with the Nevada-Sonoran region,[2] and considers the Mexican "highland" as a part of his Basin-and-Range province lying south of the Colorado Plateau. Toward the south in trans-Pecos Texas the Colorado Plateau and the Nevada-Sonoran region of Ransome are delimited by a rather vague boundary from the Mexican Plateau, which Ransome also considers a part of the Laramide mountain system. The Mexican Plateau comprises the high plateaus and central mountains of Mexico. Southward from Rio Grande, below the mouth of Pecos River, it forms the western boundary of the Coastal Plain. The boundary, according to Hayes (oral communication), is a fault scarp which lies a little east of Monterey and trends east of south through Ciudad Victoria to Misantla, where volcanic mountains reach the shore and interrupt the continuity of the plain. The province is terminated on the south by a fault scarp beyond which are the east and west trending structural axis of Michoacan, Guerrero, and Oaxaca.

4. *Oaxaca-Guerrero.*—A structural axis extends through Michoacan, Guerrero, and Oaxaca, almost at right angles to the trend of the Mexican Plateau. The northern boundary of this province is the escarpment at the southern margin of the Mexican Plateau; the western and southern boundary is the Pacific Ocean; while the eastern boundary is the Isthmus of Tehuantepec. It is thus set off from the Mexican Plateau, and the Yucatan lowland.

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[1] Ransome, F. L., The Tertiary orogeny of the North American Cordillera and its problems, Problem of American geology, pp. 289-295, New Haven, 1915.

[2] Fenneman, N. M., Physiographic divisions of the United States, Assoc. Amer. Geographers Bull. vol. 6, p. 41, 1916.

5. *Yucatan.*—This province consists of lowlands, under 600 meters in height, underlain by only slightly deformed Tertiary strata, except some problematic rocks west of Belize. The Yucatan Peninsula and Campeche Bank are comparable to the Floridian Plateau. They are developed along a structural axis almost at right angles to the continental trend. Campeche Bank projects northward from the shore line of the peninsula 170 nautical miles to the 100-fathom curve and has a width of nearly 360 nautical miles along an east and west line. On the east the depth of water between it and Cuba exceeds 1,000 fathoms and the axial trends are not coincident, but the axis of Yucatan Bank and that of the Province of Pinar del Rio, Cuba, curve so that they are nearly parallel, with a trough, Yucatan Channel, between them.

6. *Guatemala-Chiapas.*—This province lies between the Yucatan lowland on the north and Rio Motagua on the south. It is an upland dominated by east and west tectonic lines, and has been called the Guatemala-Chiapas Plateau by Tower.[1]

7. *Cuba.*—This province is coincident with Cuba and its submarine continuation, the Cayman Ridge. At least four subdivisions should be recognized: (1) The Isle of Pines, which is composed of mountains of schists and marbles with piedmont plains and marsh, separated from the main island by water less than 10 fathoms deep. (2) Organos Mountains of Pinar del Rio and the accompanying piedmont plains. The 1,000-fathom curve is less than 20 miles off the north shore. (3) Central Cuba, from the east end of Organos Mountains to Cauto River, is mostly a plain broken by some hills of serpentine and granite, and in Santa Clara Province, near Trinidad, mountains reported to be composed of Paleozoic sediments attain an altitude of about 2,000 feet. (4) Sierra Maestra and Cayman Ridge. This subprovince lies between the Cauto Valley and the south shore and is continued westward as the submarine Cayman Ridge, along the axis of which only the Cayman Islands project above water level. The axial trend is nearly east and west between Cabo Cruz, Cuba, and Little Cayman, whence it curves to the southwest and pitches toward the head of the Gulf of Honduras, which is an area of depression. Between the Caymans and the Isle of Pines the depth of water exceeds 1,000 fathoms, while the Bartlett deep to the south, separating Cuba and Jamaica, exceeds 3,000 fathoms in depth.

7*a*. *Haiti, northern part.*—The island of Haiti lies at the convergence of the trend of the axis of the central subprovince of Cuba and the Honduran-Jamaican axis. The dividing line in Haiti is from Port au Prince to Ocoa Bay. The area south of this line belongs to a Jamaican axis, while that to the north belongs to the central

[1] Tower, W. L., Investigation of evolution in chrysomelid beetles of the genus Leptinotarsa, Carnegie Inst. Washington Pub. No. 48, p. 50, 1906.

Cuban trend. The structural axes of the mountains in the northern and northeastern part of Haiti are from northwest to southeast and are parallel to the axis of elongation of Cuba from the Sierra Maestra to Santa Clara. In Cuba this trend is cut diagonally by the axis of the Sierra Maestra, which is bounded on the south by a tremendous fault scarp. Previous to this faulting it seems that central Cuba and Haiti formed parts of the same land area. The island of Haiti might be treated as separate from Cuba and Jamaica, but lying at the intersection of two tectonic trends.

8. *Honduras and the Jamaican Ridge.*—The Honduran Province in Central America is dominated by tectonic lines extending from southwest to northeast, of which the Telusa Mountains are representative. A line from the Gulf of Honduras along Motagua River to a point north of Jalapa, thence southwest to the Pacific coast, may be taken as the northern boundary and Rio San Juan and the southern side of Lake Nicaragua as the southern boundary.

From the northeast coast of Honduras and Nicaragua a great submarine plateau continues with depths of less than 1,000 fathoms to Jamaica. Above it rise numerous banks and keys and along its course are Thunder Knoll, Rosalind, Seranilla, and Pedro banks between the continental shore and Jamaica.

The principal old tectonic lines of Jamaica trend northwest to southeast. As these are parallel to the shore northwest of Cape Gracias a Dios and to the northeast edge of Mosquito Bank, there are evidently cross tectonic lines nearly at right angles to each other in this ridge.

A submarine ridge extends from the east end of Jamaica some 45 miles and overlaps on the south side a ridge which protrudes westward from the west end of Haiti. The two ridges, however, do not connect but are separated by water over 1,000 fathoms deep. The ridge representing an eastward submarine continuation of Jamaica indicates a third tectonic line in that island. The last-mentioned line nearly parallels the Bartlett deep, which lies to the north. The submarine slopes to the southeast are toward the bottom of the Caribbean basin.

8*a*. *Haiti (southern part), Porto Rico, and the Virgin Islands.*—The political division of Haiti designated Sud is dominated by east and west trending mountains, which parallel in direction the east and west axis of Jamaica. As the maximum depth between Haiti and Porto Rico is about 318 fathoms, they rise from a common, not greatly submerged bank. (See statement on preceding page in regard to considering Haiti as a separate Province.)

The main mountain mass of Porto Rico, the Sierra Central, the maximum altitude of which is 3,750 feet at El Yunque, trends east and west, paralleling in direction Sud, Haiti. There is coincidence

in the direction of elongation of the Jamaican bank, Sud (Haiti), and Porto Rico.

The relative truncation of the west end of Porto Rico, except the protuberant which forms Cabo de San Francisco, is striking and suggests faulting. The declivities both to the north and south of the island are great, over 4,000 fathoms in depth being reached within 40 miles of the north coast, while 2,000 fathoms are attained within a shorter distance from the south coast.

A submarine bank extending from the east end of Porto Rico to Anegada Passage is known as Virgin Bank. The depth of water between the islands rising above this bank is less than 20 fathoms, which is a minimum for the amount of submergence they have recently (geologically speaking) undergone. These islands are detached outliers of Porto Rico.

8*b*. *Saint Croix.*—Although St. Croix is separated from the Virgin Islands by a depth as great as 2,400 fathoms and is joined to the St. Christopher chain by a ridge less than 1,000 fathoms deep, it possesses great similarity to members of the Virgin group. The west end is truncate and the submarine slope precipitous; the submarine slope to the north is also steep. There is clear evidence of faulting on the west and north sides. A ridge, largely of igneous rock, stands against the north shore from the west end of the island for some distance to the east. South of the ridge is a sloping, rolling, calcareous plain. The east end has a submarine continuation in a bank less than 50 fathoms deep. The tectonic axis is east and west, the rocks resemble those of the Virgins, and the zoogeography indicates former connection with them. For these reasons it seems probable that this island was formerly a part of the Porto Rican-Virgin Island land-mass and has been sundered from it by diastrophic processes. However, Saint Croix might be accorded separate status as a province, or referred to the St. Christopher axis; but it appears to me preferable to classify it with the Virgin Islands.

9. *Costa Rica-Panama.*—Between the Nicaragua-Costa Rican boundary and the mouth of Rio Atrato is an S-shaped land area which does not exhibit striking major tectonic lines, although some deformation axes are obvious in Panama. The region is largely one of vulcanism, present or past, which although occurring within definable limits does not follow continuous straight axes but occurs in a curving belt. The topography appears disordered, with volcanic protuberants here and there without perceptible system. The volcanic heaps range from a few hundred to nearly 10,000 feet in altitude.

10. *Andes.*—The south-north trending ranges of the Andes reach the shores of the Caribbean Sea between the Gulf of Darien and Venezuela, and send a spur, Cordillera de Merida, northeastward to

Porto Cabello where the main Andean trend is crossed by that of the Maritime Andes. The shore of the Caribbean Sea lies across the northern end of the Andes in a way similar to the manner in which the landward border of the Coastal Plain crosses the southwestern end of the Appalachian Mountains.

The islands Curaçao, Arube, and Bonaire, lie off the Venezuelan coast in the angle between the ends of the main Andes and the Cordillera de Merida.

11. *Maritime Andes.*—The Maritime Andes lie along the Venezuela coast from Caracas eastward. Trinidad and Tobago are outlying islands. On the south side of these mountains is the great Valley of the Orinoco.

12. *Caribbean Islands.*—These islands lie along triple arcuate ridges, the Barbadian Ridge, the main Caribbean Arc, and Aves Ridge, the second of which is double at its northern end.

12*a*. *Barbadian Ridge.*—As Barbados is connected undersea with Tobago Island by a ridge less than 1,000 fathoms deep, and as the depth between it and St. Lucia is less than 1,000 fathoms, there is a closed basin over 1,000 fathoms deep between the Barbadian Ridge and the main Caribbean Arc.

12*b*. *Caribbean Arc.*—The Caribbean arc is a ridge that extends from north of the Gulf of Paria to Anegada Passage. The islands occurring along it from the Grenadines to Dominica are entirely or predominantly volcanic. Guadaloupe is a compound island; the western half is volcanic, the eastern half with the outlying Marie Galante is mostly composed of calcareous sediments. North of Martinique the arc splits; along the inner fork are the volcanic islands Montserrat, the St. Christopher Chain, and Saba; along the outer fork are Antigua and Barbuda, and the St. Martin group. The latter islands are largely or predominantly composed of sedimentary rocks resting on an igneous basement of pre-Tertiary or early Tertiary age.

12*c*. *Aves Ridge.*—This ridge takes its name from Aves Island, which stands on a ridge running from the north coast of Cumana to Saba Island at depths slightly less than 1,000 fathoms, while water of greater depth occurs both east and west of it.

Paleographic Summary.

There are many publications dealing with this subject, some of which, such as those of Gregory,[1] Hill,[2] and Guppy,[3] are specially

[1] Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, pp. 255-310, pl. 11, 1895.

[2] Hill, R. T., Notes on the geology of Cuba, based upon a reconnaissance made for Alexander Agassiz, Mus. Comp. Zoöl. Bull., vol. 16, pp. 243-288, pls. 3-9, 1895; The geological history of the Isthmus of Panama and portions of Costa Rica, Idem., vol. 28, pp. 159-285, pls. 1-19, 1898; The geology and physical geography of Jamaica, Idem., vol. 34, pp. 1-226, 252-255, pls. 1-35, 1901; Pelée and the evolution of the Windward Archipelago, Geol. Soc. America Bull., vol. 16, pp. 243-288, pls. 43-47, 1905.

[3] Guppy, R. J. L., The geological connexions of the Caribbean region, Canada Inst. Trans., vol. 8, pp. 373-391, one plate, 1909.

devoted to the West Indies and Central America, or consider parts of the regions; others are devoted to the geologic history of smaller areas that are parts of the region and are too numerous for mention here, but many of them have been referred to in my papers on the fossil corals and the correlation of the geologic formations of Panama, forming parts of this volume; while still other works, for instance those by Schuchert [1] and Willis,[2] treat Central America and the West Indies only as parts of much larger areas.

Schuchert in his work cited undertakes to reconstruct for this region the distribution of land and sea; that is, connections and barrier between the Atlantic and Pacific Basins during Paleozoic time, basing his inferences upon the affinities of the Paleozoic faunas. As I can add nothing to what he says, I will not summarize his conclusions—the reader may consult his memoir.

LATE PALEOZOIC.

The great Appalachian revolution occurred in late Paleozoic–Permian time, and resulted in the northern boundary of the Gulf of Mexico—the southern Appalachian, the Ouachita, and Wichita Mountains.

The east and west trend in southern Mexico already existed or was developed about this time; while farther to the southeast, as Sapper has shown, Rio Motagua in Guatemala divides two chains of this age, one to the north, the other to the south, with spurs of a third chain farther toward the southeast. The nearly north and south trend of the Coxcomb Mountains in British Honduras, which are composed of sediments apparently of pre-Paleozoic age indicates that the Yucatan protuberant had been outlined in Paleozoic, perhaps early Paleozoic time. Granitic débris in Costa Rica and Panama suggests old deformation along east and west lines in those areas. The east and west mountains of Venezuela have an old foundation and certainly date back to the Paleozoic in origin. There is evidence of old deformation in Cuba, rendering it highly probable, if not certain, that the major tectonic trends of Cuba are as old as Paleozoic. Although no Paleozoic rocks have been identified in Jamaica, the inference appears warranted that Jamaica itself dates back to late Paleozoic, as it has been shown by Sapper that the west end of the tectonic features represented in Mosquito and Rosalind Banks and Jamaica already existed in late Paleozoic time. The Cuban and Jamaican trends meet in Haiti and continue through Porto Rico to the Virgin Islands,

[1] Schuchert, Charles, Paleography of North America, Geol. Soc. America Bull., vol. 20, pp. 427–606, pls. 46–101, 1910.

[2] Willis, Bailey, Paleographic maps, in Outlines of geologic history with special reference to North America, pp. 306, Chicago, 1910.

while St. Croix, which is closely related in its geologic features to the Virgins, was probably at one time a member of that group and has been separated from them by faulting of comparatively late geologic date. There is no direct evidence of the existence at this time of any of the Caribbean Islands, but certain relations suggest that at least parts of the Caribbean Arc may be old. St. Croix stands on the western end of a ridge between 600 and 700 fathoms deep, on the eastern end of which is St. Christopher. This ridge extends northward to the St. Martin Plateau, eastward to Antigua and Barbuda, and southward from the latter islands through Guadeloupe, St. Lucia, and the Grenadines to South America. These relations suggest that the eastern perimeter of the Caribbean Basin may have been outlined in late Paleozoic time.

From the preceding statement it is evident that the principal tectonic lines of the perimeters of the Gulf of Mexico and Caribbean Sea existed at the close of the Paleozoic. The northern, western, and southern boundaries had been outlined and the major transverse trends had also been formed, the more northern through Oaxaca and Chiapas, including the northward trending Coxcomb Mountains of British Honduras; the more southern through Honduras and Nicaragua. The first may have connected along the axis of the Coxcomb Mountains with Cuba and thence Haiti; the second probably connected with Jamaica, Haiti, Porto Rico, and the Virgin Islands, and there are vague suggestions that the Caribbean Arc also existed. As the positive and negative areas so early outlined dominated the tectonic development during later geologic time, the subsequent history consists in tracing the modification of these old features.

TRIASSIC, JURASSIC, AND CRETACEOUS.

It seems necessary to infer diastrophic movements previous to or during Jurassic and Cretaceous time, for there was no connection between the Atlantic and Pacific oceans across Central America during these periods, with the possible exception of certain connections during Jurassic and upper Triassic (Karnic) time, as shown in the table on page 612. During Triassic and Jurassic time the eastern part of the North American continent, except areas of Triassic in Mexico and several Central American States and areas of Jurassic in Mexico and trans-Pecos Texas, was emerged probably to the limits of the present Continental Shelf, while the western end of Cuba was submerged. The eastern end of Cuba apparently was a land area and may have been joined to the southeastern United States. During upper Cretaceous time there was extensive submergence throughout the West Indies and Central America, but the Lower Cretaceous, as represented in Mexico and Texas, is not known in them, except in Honduras. As the Jurassic and Cretaceous faunas are Atlantic in their facies,

the Atlantic Ocean must have had access to these oceanic basins during a part if not all of these periods.

According to Hill, vulcanism existed prior to later Mesozoic in Guatemala, Oaxaca, Jamaica, and the Andes, and perhaps in Cuba and Haiti, as well as in the Cordilleras of North America. Probably there was vulcanism in Porto Rico, the Virgin Islands, St. Croix, St. Martin, St. Bartholomew, and Antigua. In the two last mentioned islands there are volcanic rocks older than Eocene sediments.

At the close of the Cretaceous there was general emergence of the Coastal Plain, an event probably due to diastrophism and a resultant of Laramide mountain making.

EOCENE AND OLIGOCENE.

The West Indian islands, because no old Eocene sediments are known in any of them except Trinidad, which is South American in its relations, are supposed to have stood above sea level at that time. In Cuba and Jamaica there are Upper Cretaceous and late Eocene sediments without the intervention of early Eocene deposits.

During later Eocene (Ludian) and middle and upper Oligocene (Rupelian and Aquitanian) time there was extensive submergence in the West Indies and interoceanic connection through a number of straits across Central America. There may have been interocanic connection during lower Oligocene (Lattorfian) time, but this is not established. The maximum submergence was in middle Oligocene (Rupelian) time. Vulcanism was widespread in Central America and the Antilles during Eocene and probably also during earlier Oligocene time. The line of the great Mexican volcanoes had its inception at the close of the Cretaceous, near the beginning of the Tertiary, according to Felix and Lenk.

In Jamaica, Cuba, St. Bartholomew, and Antigua the later Eocene age of some of the volcanic rocks is established. There was between the upper Eocene and the middle Oligocene deposition periods great deformation in the Antilles. The folding in the principal mountains of Jamaica, the Sierra Maestra of Cuba, and apparently those of Haiti, Porto Rico, the Virgin Islands, and St. Croix appears to have taken place at this time. Diastrophism seems also to have been active in Chiapas, Tabasco, Petén, Guatemala, Nicaragua, Costa Rica, and Panama.

MIOCENE.

During older Miocene (Burdigalian) time apparently there was in places connection between the Atlantic and Pacific oceans, as is shown by deposits of this age containing fossils of Atlantic affinities on the Pacific coast of Costa Rica [1] and Nicaragua, and perhaps at

[1] Romanes, J., Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 124, 125, 1912.

other places, but such connections seemingly were restricted, not of wide extent as in upper Eocene and Oligocene time.

As no upper Miocene has yet been identified in the West Indies this is supposed to have been a period of high uplift which terminated the connection between the Atlantic and Pacific oceans. The middle and upper Oligocene and lower Miocene sediments of Mexico, Panama, Cuba, Haiti, Jamaica, Porto Rico, Anguilla, and Antigua, although deformed by tilting and faulting are not intensely folded, as are the older sediments. According to Hill, "in mid-Tertiary time granitoid intrusions were pushed upward into the sediments of the Great Antilles, the Caribbean, Costa Rican, and Panamic regions." The information I obtained in Antigua and St. Bartholomew accords with this opinion.

That there was at some place interoceanic connection subsequent to lower Miocene (Burdigalian) time is suggested, if not actually proven, by the presence on Carrizo Creek, Imperial County, California, of a coral fauna of post-Miocene Atlantic affinities.[1]

Roy S. Dickerson[2] in the paper cited below says regarding my conclusion that the coral fauna of Carrizo Creek is of probably Pliocene age: "His [Vaughan's] conclusions concerning the Pliocene age of these beds rests upon the infirm basis of comparison with a Pliocene coral fauna of Florida," and "All the coral genera except one occur in the Bowden or associated horizons." The last statement is correct in the restricted sense in which I use Bowden and its related zones, and the first is correct in that I compared the fauna from Carrizo Creek with that from the Pliocene Caloosahatchee marl of Florida; but Doctor Dickerson evidently did not comprehend the entire basis for my opinion. The following eight genera, now extinct in the Atlantic Ocean but present in the Pacific, occur in the Bowden marl and related zones, that is in Miss Maury's Santo Domingan section and the La Cruz marl of Cuba, but are not known from Carrizo Creek or from the Caloosahatchee marl:

Placocyathus.	*Antillia.*
Placotrochus.	*Syzygophyllia.*
Stylophora.	*Pavona.*[3]
Pocillopora.	*Goniopora.*

Neither the coral fauna of Carrizo Creek nor that of the Caloosahatchee marl, as at present known, contains any of the coral genera distinctive of the Bowden and related zones. These distinctive

[1] Vaughan, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, California, etc., U. S. Geol. Survey Prof. Paper 98, pp. 355–386, pls. 92–102, 1917.

[2] Ancient Panama Canals, California Acad. Sci. Proc., vol. 7, pp. 197–205, 1917 (date printed with title July 30, 1917, received by me on Oct. 16, 1917).

[3] Added from Miss Maury's Santo Domingan collections.

genera became extinct in the Atlantic during upper Miocene time, according to the present information, but, they persist in the Indo-Pacific region. It, therefore, seems that the fauna of Carrizo Creek migrated to the head of the Gulf of California after the extinction of these forms.

PLIOCENE AND LATER.

Subsequent to the Miocene there have been many oscillations of the West Indian area, and during perhaps Pliocene time there was profound deformation. Zeogeographic data in the opinion of several investigators seem to demand former connection, probably during late Miocene or Pliocene time from Yucatan across Cuba to Haiti, Porto Rico, and the Virgin Islands; from Honduras to Jamaica; and from Anguilla to South America. It also appears that St. Croix was once joined to Anguilla and to the eastern end of the Virgin Islands. There are certain geologically late fault-lines which perhaps date from this time and the severance of the old ridges into the islands we now know may be largely due to movement along them. One of these fault lines forms the northern boundary of the Bartlett Deep, and passes between the east end of Cuba and the west end of Haiti. Another tectonic line which forms the south side of the Bartlett Deep seems to converge toward the former in the Windward Passage. A down-thrown block between these lines has separated Cuba and Haiti and produced the Bartlett Deep. Probably there was also faulting or flexing between Cayman Ridge and the southern shore of Cuba, west of Manzanillo Bay, while either faulting of flexing may have separated Cuba and Yucatan. There is evidence of a downthrown fault block between St. Thomas and St. Croix, the two sides converging toward Anegada Passage. This will account for the deep of over 2,400 fathoms north of St. Croix, and the severance of St. Croix and the St. Martin Plateau group of islands from the Virgin group.

There are three kinds of evidence that bears on the age of this faulting, namely: (1) In eastern Cuba, as the Miocene La Cruz marl is abruptly cut off at the shore line in the vicinity of the Morro at the mouth of Santiago Harbor, the faulting must be subsequent to old or middle Miocene; (2) as the sea along the fault shores has been able since the faulting to cut only narrow benches into the fault planes on the up-thrown side, the faultplanes are physiographically young; (3) the biologic evidence, in the opinion of most of those who have recently considered it, demands land connection in late Tertiary time between Cuba, Santo Domingo, Porto Rico, and thence

to South America. Miller has recently published an important paper on this subject,[1] and states: "With the characters of so many [eight] genera known it becomes possible to gain some idea of the Antillean hystricine fauna.[2] The most noticeable feature of these genera considered as a group is their similarity to the Santa Cruzian and Entrerian rodents which Ameghino and Scott have described and figured. In no instance has the same genus been found in both the West Indies and Argentina or Patagonia; but the Antillean rodents thus far discovered never show such peculiarities that their remains would appear out of place among those of their extinct southern relatives, while as a whole they would at once be recognized as foreign to the present South American fauna."

On the following page of the same paper he says: "So far as can be judged from eight very distinct genera the Antillean hystricine rodents do not present the characters that would be expected in animals derived from South America during any period geologically recent. Neither have they the appearance of an assemblage brought together at different times by migration or chance introduction. On the contrary they suggest direct descent from such a part of the general South American fauna, probably not less ancient than that of the Miocene, as might have been isolated by a splitting off of the archipelago from the mainland. Of later influence from the continent there is no trace."

The mammals furnish more evidence of this kind than I am presenting here, and Barbour and Stejneger, from their study of reptiles, have reached the same conclusions. These conclusions accord with the tectonic history of the region, namely, that in late Tertiary, probably Pliocene time, the West Indian Islands as we know them were produced by block-faulting which broke into pieces a far more extensive land area. Although I greatly respect the scholarship and appreciate the valuable researches of Dr. W. D. Matthew, I am unable to agree with his opinions as to the means of distribution of West Indian mammals and some of the other land vertebrates.

According to Hill, the volcanoes of the Windward Islands date back at least to the Eocene. He says: "After the Miocene, vulcanism became quiescent in the Great Antilles and the Coastal Plain of Texas, but has continued to the present in the four great foci of present activity—southern Mexico, the northern Andes, Central America, and the Windward Islands. In the last two regions mentioned, the greater masses of the present volcanic heights were piled

[1] Miller, Gerrit S., Jr., Bones of mammals from Indian sites in Cuba and Santo Domingo, Smithsonian Misc. Coll., vol. 66, No. 12, 10 pp., 1 pl., 1916.

[2] Idem., p. 3.

up before the Pliocene, and the present craters are merely secondary and expiring phenomena."

The last important shift in position of strand line along the Atlantic coast of the United States and around the shore of the Gulf of Mexico and the Caribbean Sea has been by submergence of land areas, but subsequent to this there has been local emergence, often accompanied by minor tilting or warping.

Except vulcanism, the following table presents a succinct summary of the major events considered in the foregoing remarks. It is the primary intention of the present paper to characterize biologically and to correlate the marine formations of the Canal Zone and the geologically related areas in Central America and the West Indies, and to lay particular stress upon the successive periods of emergence and submergence of the land and the crustal deformation, folding and faulting, concomitant with changes of that kind. Comparison of the table opposite page 594, showing the correlation of the Tertiary formations of Panama, with the following tabular summary, will reveal that the story told by the two tables is essentially identical, the erosion intervals and the marine formations in the correlation table representing respectively the periods of emergence and the periods of submergence in the tabular summary.

TABULAR SUMMARY OF SOME OF THE IMPORTANT EVENTS IN THE GEOLOGIC HISTORY OF THE WEST INDIES AND CENTRAL AMERICA.

Time subdivisions.	Events.
Recent	Submergence of land areas probably resulting from deglaciation, except local differential crustal movements in places producing uplift.
Pleistocene	Emergence of large areas, probably due to withdrawal of water to form the continental ice sheets; also oscillation of land areas by differential crustal movement.
Pliocene	Local moderate submergence, period of cataclysmic faulting breaking up a large land area and forming the Antilles nearly as they are at present. Probably a narrow interoceanic connection that admitted an Atlantic fauna into the present site of the Gulf of California.
Miocene, upper	Extensive emergence of the land joining North and South America through Central America; Greater Antilles joined to each other, and possibly to Central America by bridges from Jamaica to Honduras and from western Cuba to Yucatan, and to South America along the Caribbean arc. All these supposed connections not necessarily contemporaneous.
Miocene, middle and lower	Extensive submergence in the West Indies and around the continental margins; narrow, areally limited interoceanic connections in lower Miocene time, none known in upper Miocene time; land emerging in Central America.
Oligocene, upper	Extensive submergence with interoceanic connections.
Oligocene, middle	Maximum areal submergence with extensive interoceanic connections.
Oligocene, lower	Extensive submergence in Central America and southeastern United States; local emergence in the West Indies. Extensive diastrophism and mountain making by folding.
Eocene, upper	Extensive submergence with interoceanic connections.
Eocene, middle	Apparently interoceanic connection across Central America.
Eocene, lower	Emergence of the Greater Antilles and Central America, no known interoceanic connection.

TABULAR SUMMARY OF SOME OF THE IMPORTANT EVENTS IN THE GEOLOGIC HISTORY OF THE WEST INDIES AND CENTRAL AMERICA—continued.

Time subdivisions.		Events.
Cretaceous[a]	Upper	Extensive submergence; but without interoceanic connection.
	Lower	Submergence in Mexico and Central America, especially in late Comanche time. Probable emergence in the Greater Antilles; no interoceanic connection.
Jurassic	Upper	Submergence in western Cuba, eastern Mexico, and west Texas without interoceanic connection, except possibly in late Upper Jurassic time.
	Middle	Submergence in southern Mexico (Oaxaca and Guerrero) with possible interoceanic connection.
	Lower	Submergence in southeastern Mexico (Puebla, Vera Cruz, and Hidalgo, possibly also in Guerrero) with possible interoceanic connection. Nonmarine plant-bearing beds in same region and also in Oaxaca. Possibly the latter may be of same age as the supposed Rhaetic plant-bearing beds of Honduras and Nicaragua.
Triassic	Upper (Rhaetic)	Plant-bearing beds in Honduras and Nicaragua, above mentioned, bespeak land conditions in latest Triassic or earliest Jurassic.
	Upper (Karnic)	Submergence in central Mexico (Zacatecas) with probable interoceanic connection.
	Middle	Probable land conditions throughout Mexico and Central America.
	Lower	Probable land conditions throughout Mexico and Central America.
Late Paleozoic.....		Formation of the major tectonic axes of Central America and the initial east and west axes of the Greater Antilles.

[a] Mesozoic history of Central America, Mexico, and the West Indies, by T. W. Stanton.

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